Symposium Papers

5th meeting 1954

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

CONSEIL INDO-PACIFIQUE DES PÊCHES

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SYMPOSIUM PAPERS

I PLANKTON

IPFC/C54/SYM 1 On the methodology of marine plankton collection, with a suggested classification by Z. Nakai

SYM 2 On the nutritional relationships between plankton and fish in Indonesian freshwater ponds by K.F. Vaas

SYM 3 Some factors controlling algal production in salt water lagoons by V.K. Pillai

SYM 4 Hydrology and seasonal fluctuations of the plankton in the Hooghly estuary by N. Dutta, J.C. Malhotra and B.B. Bose

SYM 5 Studies on the blue-green algae in Japan by T. Harada

SYM 6 Observations on the distribution and fluctuations of planktonic larvae off Mandapam by R.R. Prasad

SYM 7 A preliminary study of the plankton of the Chilka Lake for the years 1950 & 1951 by M.P. Devasundaram and J.C. Roy

SYM 8 The role of planktonology in fisheries development by Tham Ah Kow

SYM 9 A preliminary study of the hydrology and fauna of the Vellar estuary (South Arcot Dt. S. India) by K. Ramamurthi

SYM 10 Variations in zooplankton abundance in the Central Equatorial Pacific, 1950-1952, by J.E. King

SYM 11 Feeding habits of the pond-smelt, Hypomesus Olidus and the plankton succession in Lake Suwa (PT.1), by Y. Shiraishi.

SYM 12 On plankton research in Japan with an annotated bibliography by S. Motoda.

Note: IPFC/C54/TECH3 - "The Role of pH in pond fertilization" should also be considered here.

II MARKETING

IPFC/C54/SYM II-1 Some Important Socio-economic Problems of the Fishery Industries of Japan, by N. Oka, I. Konuma, K. Yamamoto and M. Abe.

SYM II-2 Problems of Fish Marketing in the State of Orissa, by G.N. Mitra.

SYM II-3 A Note on Marketing and Preservation of Fish in Saurashtra, by K.R. Srivatsa.

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5th Meeting, Bangkok, Thailand
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IPFC/C54/SYM1

ON THE METHODOLOGY OF MARINE PLANKTON COLLECTION, WITH A SUGGESTED CLASSIFICATION

by
Z. Nakai*

INTRODUCTION

The difficulties encountered in making quantitative plankton surveys, and the numerous controversies which arose in regard thereto at the end of the 19th and the beginning of the 20th centuries, have been described (inter alios) by Johnstone(10), while Herdman(11) has suggested that the only way of overcoming these difficulties is "more frequent sampling and more accurate and detailed determination of the characters, both physical and biological, of the various areas, currents and zones of waters making up our seas - and all that is being done, and must be done in still greater detail, by oceanographers all over the world."

Because of the remarkable morphological and ecological differences encountered in plankton, and because of the great range of population densities from time to time and from place to place, it has not been found practicable to devise any single method of sampling which will give uniformly acceptable results and which would be applicable to every area and to every occasion. However convenient it might be to have such a uniform, all-purpose system available, we are nevertheless confronted with the fact that not always is the same degree of precision essential for every purpose for which plankton is collected, and many factors, of which financial considerations are not the least important, may have to be taken into account when deciding the methodology to be adopted for a particular type of survey.

Certain over-all aspects are of course, axiomatic for some specific classes of investigation; for instance, water sampling for determining nanno-plankton, fine nets for micro-plankton, coarser nets for macro-plankton etc.; but if a broader view is taken, it will be seen that many other diagnostic features must be considered besides this conventional grading by size, depending on the particular aims pursued, especially where ecological conditions, population density and the relationships of plankton to the fisheries are the chief considerations.

PRE-REQUISITES FOR STANDARDIZATION

With these views in mind, I believe that a series of pre-requisites should be considered before any international standards can be established in regard to the physical properties of sampling apparatus or the methodology to be employed. This is especially true in the Indo-Pacific region,

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where there is a small number of plankton workers separated by vast distances. These pre-requisite steps are:-

1) Determination of the general purposes for which sampling is to be undertaken according to the requirements of different regions or different fisheries, and of the degree of precision required for those purposes. This may be influenced by the information already available on morphology, distribution and other ecological factors;

2) The sorting of these essential conditions (purpose, precision, biological information) into different types of collecting according to the requirements of and the data supplied by the interested countries;

3) On the basis of 1) and 2), determination, after discussion, for which of the essential types of collection it is feasible and advisable to lay down international standards, taking into account the practical and economic possibilities as regards research vessels, instruments, man-power etc.

4) Finally, the specification for each of the above categories of the type of apparatus to be employed (pump, water bottle, net etc.) together with the physical specifications (quality of materials and in the case of nets, size of mesh with special consideration of clogging effects and selectivity for size; flowmeters to evaluate water straining coefficient; towing methods (horizontal, vertical, oblique etc.), speed and duration of tow; depth of operation; closing devices if any, etc.

One important consideration which must always be kept in mind is that any standard technique which might be adopted should never obstruct the possible future introduction of new and improved methods or devices; however, such changes in standards should only be considered after a careful comparison of their respective merits and adequate precautions must always be taken so as to avoid confusion and in order to establish comparability between the old and the new standards.

SUGGESTED CLASSIFICATION SYSTEM

As a guide in determining the purpose for which sampling is to be undertaken, and as an alternative to grading according to morphological considerations, the writer has in a previous paper(1) attempted to classify plankton into several categories each having a specific relation to the commercial fisheries. It will be easily appreciated that this survey is still most incomplete in scope and detail and its submission here is therefore of an entirely interim nature.

The biological problems involved in any basic study of the fisheries are at least as complex as the industries themselves and this is particularly true in the world of plankton, which is one of the principal links in the chain of food organisms. Plankton may be classified according to morphology, ecology, physiology, bio-geography and many other attributes. When attempting a classification according to the relationships existing between the plankton and the commercial fisheries, it often becomes necessary to place a particular organism in more than one category, as will be seen from the following list. Each category is subsequently discussed in detail, while Table I gives a brief analysis of type locality and seasons of occurrence in Japanese waters, utility and relation to the fisheries, in respect of one species chosen to represent each of the proposed categories.

1.1.EXPLOITABLE PLANKTON (EX PLANKTON)+

A. Immediately Exploitable Plankton (IE Plankton)
   a. Human Consumption Plankton (HC Plankton)
   b. Bait-Use Plankton (BU Plankton)
   c. Farm-Use Plankton (FU Plankton)

+The recent hypothesis that the phytoplankton might in the future be directly exploited for human food is not discussed here.

B. Exploitable-in-Future Plankton (EF Plankton)
  a. Fish-Egg Plankton (FE Plankton)
  b. Fish-Larval Plankton (FL Plankton)

2. FISH-RELATED PLANKTON (FR PLANKTON)

A. Direct-Food Plankton (DF Plankton)
  a. Zooplankton (DFZ Plankton)
  b. Phytoplankton (DFP Plankton)
B. Indirect-Food Plankton (IDF Plankton)

C. Injurious Plankton (INJ Plankton)
  a. Water-Polluting Plankton (WP Plankton)
  b. Spawn-Predatory Plankton (SP Plankton)
D. Symbiotic Plankton (SB Plankton)

3. FISHING-RELATED PLANKTON (FGR PLANKTON)

A. Fish-Indicator Plankton (FIND Plankton)
  a. Direct-Food Plankton (DF Plankton)
  b. Indirect-Food Plankton (IDF Plankton)
  c. Coinciding-with-Fish Plankton (CF Plankton)
  d. Adverse Indicator Plankton (AD Plankton)
  e. Luminous Indicator Plankton (LI Plankton)
B. Fisherman-Disabling Plankton (FD Plankton)
  a. Gear-Impairing Plankton (GI Plankton)
  b. Echo-Sounder-Deceiving Plankton (ESD Plankton)
  c. Physically Injurious Plankton (PHI Plankton)
  d. Water-Darkening Plankton (WD Plankton)
  e. Catch-Affecting-Luminous Plankton (CAL Plankton)
  f. Catch-Plundering Plankton (CP Plankton)

1. EXPLOITABLE PLANKTON (EX PLANKTON)

Included in this category are those plankters which may be regarded as direct objectives of fishing either in their existing form or after future transformation. They fall into a few subdivisions according to their utility and developmental stages, as follows.

A. Immediately Exploitable Plankton (IE Plankton)

a. Human Consumption Plankton (HC Plankton): This type of plankton includes relatively important organisms utilized for immediate human consumption. There are for instance in Japan numerous fishing villages the economy of which is supported by the commercial fishing of the post-larvae of the anchovy, Engraulis japonicus, although the capture of the fish at this early stage of life has long been a controversial topic in relation to the conservation of the fishery resource.

It has been observed that some plankton organisms seem to have occasional toxic effects; however, no specific category has been set up for them at this time, pending further scientific information.

b. Bait-Use Plankton (BU Plankton): Included under this subdivision are the forms which are used for bait in angling or long-line fishing, and for the chum of seiners. In some types of fishing they are used for luring fish within the operational range of the gear.

c. Farm-Use Plankton (FU Plankton): Among the plankton forms which grow profusely inshore, some are readily caught by simple fishing gear for use as food in fish culture and animal husbandry. Once in a while they may be utilized as an organic manure on farm lands.

B. Exploitable-in-Future Plankton (EF plankton)

Most aquatic animals in their early stages of development lead a planktonic life as pelagic eggs or larvae. The greater part of them belong to the meroplancton and the survivors are subject to capture sooner or later as adults. As was pointed out by Hjort (2) and others, the mortality of every organism is critically high during its early life stages, so that the magnitude of the marine resources depends on the survival rate. The plankton falling into this category is therefore very important from the view-point of commercial fisheries and may be divided into two subgroups: a) Fish-Egg Plankton and b) Fish-Larval Plankton.

2. FISH-RELATED PLANKTON (FR PLANKTON)

This group includes not only those forms which serve directly or indirectly as the food of economically important fishes, but also those which have a favorable influence other than as food, or an unfavorable one through preying on them or dispersing their aggregations.

Quantitative, qualitative, seasonal, and geographical distribution of the plankton referred to here is intimately related with various biological phases of the economic fishes such as growth, nutriment, propagation, migration, distribution, and magnitude of stocks. Information on these organisms is essential to research on resource conservation and in forecasting fishing conditions.

A. Direct-Food Plankton (DF Plankton)

Many species whales, fishes and mollusks take plankton directly as their food. This direct food plankton as classified into two well established types: a) Zooplankton (DFZ Plankton) and b) Phytoplankton (DFP Plankton).

B. Indirect-Food Plankton (IDF Plankton)

Practically every type of plankton may be considered to fall under this category, provided that feeders of them are in turn preyed on by other economic species. There are of course many marine organisms, e.g. some species of benthos and large sized migratory fishes, which do not directly feed on the plankton, although they are dependent for their life on the supply of other forms which in turn feed either on living plankton or at the carcasses of plankton, in which case, plankton becomes the indirect source of nutrition. In particular, phytoplankton is an indirect nutrient of all the higher animals, which, being themselves unable to synthesize organic matter from inorganic substances, are eventually dependent on plant life.

C. Injurious Plankton (INJ Plankton)

a. Water-Polluting Plankton (WP Plankton): Occurring in abnormal concentrations, the water-polluting plankton often inflicts chemical or physical harm on economic aquatic organisms. This type of plankton sometimes drives other organisms away or obliges them to evade the area where it grows. This type of outburst appears to exclude all other forms of life and certain of these phenomena are known in English as "red tides" or "brown tides" and among Japanese fishermen by various names such as "akashio" (red water), "yakumizu" (evil water), "yodo" (stagnant water), "nigashio" (bitter water), and "kusare mizu" (spoiled water). Fishing and the culture of shellfish and seaweeds along coastal areas and in sheltered bays frequently suffer heavy damage from these invasions.

b. Spawn-Predatory Plankton (SP Plankton): Those organisms which prey on eggs and larvae of economic fishes or are harmful to their development are included in this category. Since the growth and distribution of plankton fluctuate to a considerable extent depending on the environment, the relationship between SP Plankton and its potential victims cannot be neglected when considering the economic marine resources. Plankton which consumes the larger, adult forms, is discussed under Catch-plundering Plankton (CP Plankton).

D. Symbiotic Plankton (SB Plankton)

Little attention has been paid to that type of plankton which appears to be in a state of symbiosis with economic fishes. Nevertheless, young fish of some species are from time to time reported to associate with jellyfish. The author was able to observe "kita yurei kurage" (north ghost medusa), *Cyanea capillata* Eschscholtz being followed by a host of the young of "komai" or wachna cod, *Eleginus novaga* (Kolreuter). The observation led me to the assumption that the latter fish would escape from its enemies' attack under the shelter of the former, while the medusa could easily feed on the latter's enemies approaching them. However, a question as to whether or not animals in these cases are really in symbiosis with each other, still remains to be proved. They are not, therefore, at present considered important to the commercial fisheries.

3. FISHING-RELATED PLANKTON (FR PLANKTON)

Information on standing crops of plankton in an area often facilitates the detection of fish shoals and hence the location of profitable fishing grounds. Little attention has, however, been given to the relationships existing between plankton and various other factors involved in fishing such as gear, methods, efficiency of operation and size of catch. We will deal with these problems under separate categories.

A. Fish-Indicator Plankton (FIND Plankton)

As is mentioned in a previous paragraph, the majority of plankton serves directly or indirectly as food for economic marine life. Although some of the species are harmful and repellent to fishes, it is probable that the occurrence of plankton is almost always associated in some way with the presence of economic fishes. For this reason, the distribution of plankton and its quantitative, qualitative, seasonal, diurnal, and geographical occurrence, has much to do with the distribution, migration and the detection of the existence of marine animals.

a. Direct-Food Plankton (DF Plankton): The relationship between distribution of aquatic animals and the food on which they depend can be made use of in selecting a fishing ground. Certain types of commercial fisheries are making use of this technique.

b. Indirect-Food Plankton (IDF Plankton): An animal in a higher order may depend indirectly on the presence of other, lower organisms even though they do not enter directly into its food. Plankton in such an association with economic fish may be used as an indirect indicator of fishable waters.

c. Coinciding-with-Fish Plankton (CF Plankton): There are some plankton and economic fishes which occur in a common environment, although there is apparently not a food relationship. In such cases, proper judgement on the periodical occurrence, amount and geographical distribution of fish may sometimes be determined from the presence of this type of plankton.

d. Adverse Indicator Plankton (AD Plankton): In contrast with direct and indirect food planktons, there is another type of plankton which is either detrimental or unrelated to fish life. Some of these may be actually harmful to fishes and often drive them away. Others may live in an environment altogether different from that suitable for fishes. It may therefore not be profitable for fishermen to operate in an area where these types of plankton are found. In other words, the plankton provides fishermen with a negative indicator.

e. Luminous Indicator Plankton (LI Plankton): As is known among fishermen in Japan and elsewhere, movements of fish through the water sometimes stimulate a phosphorescent glow caused by certain luminous plankton. In consequence, fishermen operating at night are able to judge as to the size and location of a shoal of fish and decide whether to cast their nets in that particular water. These phenomena are known by Japanese fishermen as "hiki" or "shirami" (phosphorescent glow).

B. Fisherman-Disabling Plankton (FD Plankton)

All the plankton which affects fishing operations, either by physical attack on the fishermen of by affecting the fishing gear is included here. This type of plankton may seriously hinders fishermen and affect the size of their catch.

a. Gear-Impairing Plankton (GI Plankton): Fishing gear such as drift nets, round hauls, boat seines, and fixed nets, will decompose faster than usual if certain kinds of plankton adhere to them while immersed. It frequently happens that purse seines and boat seines are damaged as a result of hauling up unexpectedly large numbers of unwelcome visitors such as jellyfish, and on such occasions fishermen may even have to allow their catch to escape from the net. Concentrations of the plankton may even represent too great a risk to costly nets to justify fishing, and operations may have to be abandoned for days until the plankton disappears from the water.

b. Echo-Sounder-Deceiving Plankton (ESD Plankton): Needless to say, the recent development of echo-sounders has made a remarkable contribution to fishing techniques. As yet difficulty in distinguishing a host of medusas or similar plankton from fish shoals by this device may deceive fishermen into hauling up the useless plankton instead of the fish sought after.

c. Physically Injurious Plankton (PHI Plankton): It not infrequently happens that fishing divers are attacked by a poisonous medusa whose nematocyst causes severe pain and even dangerous illness. Fishermen on board a boat are also liable to injury through mishandling medusas which are often mixed with the catch.

d. Water-Darkening Plankton (WD Plankton): Phytoplankton in general is apt to decrease the transparency of the water to some extent, occasionally disturbing the migration and distribution of fish by an excessive concentration. Another effect of this decrease in transparency may be to inhibit photosynthesis and therefore reduce the productivity of the deeper water. Here we refer, however, only to those phenomena which hamper fishing efficiency. There are fishermen in this country who harvest fish and seaweeds with the help of a glass frame, or goggles. In the case of a spring burst of phytoplankton, visibility through the water may be so much reduced as to involve serious losses of fishing time.

In other cases, the light of lamps used to attract fishes may not penetrate through the water under such adverse conditions, and this again will seriously affect the catch. This is cited as one of the reasons why most of the fishing boats in the northernmost part of Japan have not been equipped with fishing lamps, which are of little use in the presence of dense planktonic concentrations.

e. Catch-Affecting-Luminous Plankton (CAL Plankton): The luminous plankton will on the one hand assist fishermen in locating fishing grounds as described in a foregoing paragraph. On the other hand, when several boats gather together in an area, this plankton may have an adverse effect on fishing operations, on account of the phosphorescent glow stimulated by the manoeuvering of the boats and nets which tends to frighten the fish.

f. Catch-Plundering Plankton (CP Plankton): It is sometimes the case that long-line fishermen operating for cod and similar species find that their catch has been eaten up by a swarm of plankton before the hooked fish can be hauled in, and the same of course may happen to the bait. Such plankton may be called catch plunderers.

CONCLUSIONS

The useful classification of plankton for fisheries purposes does not depend upon the conventional grading by size, and standard methods will be determined according to 1) purpose of survey, precision required and biological circumstances, 2) the consequent establishment of different methods of collection and 3) economic considerations. An attempt is made to classify the plankton into numerous categories each having relation to the fisheries.

My thanks are due to Mr. Ichitaro Gensho, Director of the Tokai Regional Fisheries Research Laboratory, who has provided much encouragement in the preparation of this report, to Mr. Masao Ishida of the same Laboratory, who has assisted in translating the Japanese manuscript into English, and to Dr. Cecil Miles, Secretary, IPFC, for the final editing.

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SOME EXAMPLES OF MARINE PLANKTON IN JAPANESE WATERS
Classified by Utility and Relation to Fisheries

	Classification*	Example of Plankton++	Type Locality in Japan	Occurring Season in Japan	Utility and Relation to Fisheries	Reported by+++
Economic Plankton	HC P	Post-larva of anchovy, Engraulis japonicus T.&S.	All the coastal waters except the northern region	Nearly throughout the year	Man's food	Nishikawa, T. 3/
	BU P	Medusa, Stomolopus nomurai (Kishin ouye)	Off Iki and Tsushima Islands, Nagasaki Prefecture	May to June	Bait of long-line fishing for sea bream, Pagrosomus major (T.&S.)	Nakai, Z. 1/
	FU P	Mysis, Acanthemysis sagamiensis (Nakazawa)	Off Kanagawa Prefecture	Throughout the year	Food for fish culture, livestock; occasionally used as manure.	Nakazawa, K. 4/
	FE P	Egg of sardine, Sardinia melanosticta (T. & S.)	Coastal areas of Kyushu, coastal areas of Japan Sea	February to March March to June	To be caught in adult form	Nishikawa, T. 5/
	FL P	Larva of sardine, do.	do	do	do	
Fish-related Plankton	DFZ P	Copepod, Euphausia pacifica Hansen	Japan Sea	February to June	Food of mackerels	Nakai, Z. 7/
	DFP P	Diatom, Rhizosolenia setigera Brightwell	Coastal areas of Kyushu	February to June	Food of sardines	Nakai, Z. 6/
	IDF P	All the marine plankton			Indirect food of fish	
	WP P	Gonyaulax porigramma Stein	Ago Bay, Mie Prefecture	Autumn	A cause of "akashio" (red water) which kills pearl oyster, Pinctada martensii (Dunkar)	Nishikawa, T. 8/
	SP P	Medusa, Porpita umbella O. F. Muller	Tsushima Strait	Spring to Summer	Preys on young of mackerels and horse mackerels	Nakai, Z. 1/
	SB P	Medusa, Cyanea capillata Eschscholtz	Hokkaido	May to June	Followed by numbers of young cod, Eleginus noyaga (Kolreuter)	Nakai, Z. 1/
Fishing-Related Plankton	DF P	(Same as DFZ P and DFP P)			Reveals fishing grounds (see P. 6)	
	IDF P	All the marine plankton			Reveals fishing grounds (see P. 6)	
	CIF P	Copepod, Sapphirina spp.	North Pacific area	February to August	Indicates fishing grounds of skipjack, Katsuwonus vagans (Lesson) by co-occurrence with the fish.	Marukswa, H. 9/

(Marine Plankton in Japanese Waters - Continued)

	Classification+	Example of Plankton++	Type Locality in Japan	Occurring Season in Japan	Utility and Relation to Fisheries	Reported by+++
Fishing-Related Plankton (Contd)	AD P	Noctiluca scintillans Macartrey	Suruga Bay, Shizuoka Prefecture	May to June	Negative indication for anchovy as the fish do not occur in presence of the plankton	
	LI P	Noctiluca scintillans M.	All the coastal areas	Spring to Summer	Reveals fishing grounds of sardine through phosphorescence at night	
Fisherman-Disabling Plankton	GI P	Medusa, Aurelia aurita Lamark	Sheltered Bay	Nearly throughout out the year	Damage to gear such as boat seine and beach seine when caught an masse	Nakai, Z. 1/
	ESD P	Various medusas	Chiba Prefecture Coastal waters	Throughout the year	Affects echo-scunders of purse seiners operating for sardine and anchovy	
	PHI P	Medusa, Datylometra pacifica Gette	Coastal areas of Japan Sea	Summer to Autumn	Severe stings upon contact by fishermen.	
	WD P	Various diatoms	Coastal areas of Japan Sea	April to June	Darkens inshore waters and interrupts fishing operations	Nakai, Z. 1/
	CAL P	Noctiluca scintillans M.	All the coastal waters	Spring to Summer	Fish evades nets through luminosity.	
	CP P	Various amphypods	Coastal areas of Hokkaido	Spring to Summer	Preys on fish such as cod, Gadus macrocephalus, and pollack, Theraga chalcogramma, caught on long-line; also destroys bait.	

+ See notes and abbreviations in text.

++ Species are cited an example for each category out of numerous cases.

+++ Cited as one biologist out of many who first made a scientific report on the case. The plankton tabulated without names of reporters include those cases which are either popularly known among fishermen or are referred here on the basis of unpublished data.

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IPFC/C54/SYM2

ON THE NUTRITIONAL RELATIONSHIPS BETWEEN PLANKTON AND FISH IN INDONESIAN FRESHWATER PONDS

by

K. F. Vaas*

1. INTRODUCTION.

Many different connections exist between the many species of fish, both cultivated and free-living, and the biological association known as "plankton". Phytoplankton and zooplankton both influence the concentration of oxygen in the water and many instances are known of the excretion of toxic substances; but the most important connection is the function of plankton, either directly or indirectly, as a fish-food. At this stage a definition should be given of the term plankton which is here used to all organisms or any stages in the life cycles of organisms which are unable to resist even the weakest movement of the water, having, either very limited means of locomotion (Cladocera) or no means at all (single-celled green algae).

All the evidence goes to show that plankton is the initial food for all young fish fry immediately after the yolk-sac has been absorbed. Although this period is a most crucial one in the life of the fish, its duration can be surprisingly short, in the cases of fishes not subsisting on plankton when fully grown. According to Buschkiel (1932, 1938), the common carp in Indonesia eats nauplii of crustaceans 3 days after hatching, Tubificidae after 6 days, small Chironomides after 9, and large ones after 14 days. Young Trichogaster, of less than 1 cm. in length, can be seen to feed voraciously on periphyton.

The nutritional connection in the case of adult fishes differs considerably according to species and environment. The autotrophic phytoplankton is an important primary source of food production, on which other biota--including fish--rely in many cases, but, by no means in all.

An attempt is made in the present article to evaluate the relative importance of phyto- and zooplankton as a direct or indirect source of food for fully grown fishes in various environments, and, in the second part of the paper, to give an ecological classification of freshwater fish-ponds in Indonesia.

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or trying to do so, but are held in check by wave action, periodic drying or other natural or cultural processes.

In small and shallow lakes the influence of allochtonous detritus can be considerable. In the case of the periodically inundated forests round tropical marshes as e.g. the lakes along the R. Kapuas in W. Borneo, this, in the form of leaves and fruits from the inundated trees, plays a most important part (Vaas 1952 II).

4. PONDS.

The difference between a fish-pond and a small shallow lake where light can reach the entire bottom, is only the eventual action of the fish-farmer in operating the pond for his piscicultural purposes, which means, the introduction of fertilizers, manure or fodder and, in some cases, such cultural measures as drying the soil, eradication of weeds etc. If we try to integrate the different forms of pond culture, those where carnivorous fish are grown almost exclusively on extraneous fodder forming the one extreme, and those where phytoplankton-feeders are grown on natural food only as the other, and if we try to interprete them in terms of the food chains involved, we find the types a), b) and c), above, plus a fourth one, when fodder is used by the farmer.

```
                 ┌→Fish→Fish
d) Fodder        ├→Bacteria→Small Animals→Fish→Fish
                 │   (mineralisation)
                 │   │      ↘          ↗   ↑
                 │   │       Phytoplankton→Zoopl.
                 │   ↓                   ↗
                 └→Small Animals→Fish→Fish
```

When Salmonids are grown on refuse of the slaughterhouse, the fodder will be converted into fish flesh almost exclusively in a direct way, but in the Indonesian ponds bran is almost the only kind of fodder given, often in excessive quantities. In that case some of it will not act directly, but indirectly, via bacteria, shrimps, insect larvae etc.

It follows from the above considerations that, going from the sea, via lakes, towards ponds, in other words, as the body of water in question decreases in magnitude, we find plankton to be of decreasing importance as food for the adult fish.

The common carp, Indonesia's principal cultured fish, feeds preferably on what I have called in the previously mentioned food chains "small animals", larvae of Tentepedides, and other insect larvae, worms and crustaceans. In Indonesia domestic (not industrial) sewage is, next to the natural fertility of the soil, the principal base on which fish crops are raised. Human excreta are eaten directly by the carps, but a residue is disintegrated by bacteria on the bottom of the pond where a dense fauna of Insect-larvae, oligochaetes and crustaceans are to be found. The carps feed voraciously on these organisms and in such cases phytoplankton is unimportant for the carp even as an indirect food.

In the open sewers in some parts of Bandung City, where common carp is successfully kept in open bamboo cages, with just sufficient oxygen to keep them alive due to the flow of the water, the guts are crammed to full capacity with heads of Chironomides and remains mostly chaetae of worms. No phytoplankton and hardly any zooplankton could be found in the quickly running, brown and extremely dirty water. In the second part of this paper some figures will be given on this environment, which might be called "fish culture without phytoplankton".

On the other hand, in ordinary carp ponds phytoplankton has a strong indirect influence, as the Chironomides feed on dead and decaying algal cells e.g. of Euglena sanguinea (Ehr.)

As the fisheries biologist is not interested in the plankton per se, but in its role in the process of production of fish flesh, either by culture or by capture operations, it is hoped that the above, rather fragmentary considerations will have shown how the importance of plankton is not constant but varies with the different species of fish and with the environmental circumstances.

5. INDONESIAN FRESHWATER FISH PONDS AS AN ENVIRONMENT FOR PLANKTON AND OTHER BIOTA.

In the second part of this paper it is intended to give an ecological classification of Indonesian freshwater ponds and to point out the relative importance of plankton in these ponds.

Indonesian fish-ponds can be divided into three groups:

i) brackishwater ponds along the shallow sea coast, where Chanos chanos (Forsk.), Tilapia mossambica Peters, and various prawns are grown,

ii) paddy fields, where various forms of pisciculture, notably with the common carp, are practised,

iii) freshwater ponds, where various Cyprinidae and Labyrinthici are cultivated, sometimes as monocultures and more often in associations.

The first category was described in detail by Schuster (1949), while the author, in collaboration with M. Sachlan, gave a description of the most important biota involved. (Vaas and Sachlan 1952). The ecology of the Hawaiian Chanos ponds was described by Hiatt (1944).

This group is characterised by a marked uniformity which is lacking in the other groups as a result of the fact that the water entering the ponds is mainly seawater and the principal fish cultivated is a single species. The soil factor is the most variable one, and the work of Markus (1941), in Indonesia, is a first attempt to understand its influence. Markus found the hydrophility of the mud an important factor, as regards the growth of the complex of Cyanophyceae and Diatomeae on the bottom. He found the presence of sufficient clay particles and humus to increase, and long and often repeated periods of drying, to decrease hydrophility, thus influencing the growth of bottom-dwelling algae. In common with the brackish water ponds, an extremely limited number of fish species is cultivated in the paddy fields, but here the water factor is as variable as the soil factor. At the moment insufficient data on the biota of Indonesian paddy fields have been assembled. (vide Bernard 1908, 1909, van Oye 1921, 1922, and Vaas 1947). This is the reason why no adequate ecological classification of sawah-fish ponds can be made and the present article is limited to freshwater ponds.

For the paddy-fields in Krian (Malaya), cultivated with Trichogaster pectoralis (Regan), Soong (1952) described interesting relationships between the fertility of the soil, the occurrence of various organisms and the yield of fish. The outstanding importance of calcium is clearly demonstrated in Soong's work.

ENVIRONMENTAL FACTORS.

Various environmental factors having already been mentioned, it might be advantageous to classify them at this stage into a group of external factors influencing the eco-system of the pond from the outside, and a group of internal factors.

Within the first group the factors, sun, rain, air, inflowing and outflowing water, and--last but not least--man, in casu the fishfarmer, should be distinguished.

The second group comprises the factors, soil, water, biota other than fish, and fish.

Among the factors in the first group, sun, rain and water-supply are active in one direction only. They affect the eco-system but are not affected themselves. In other words, there is no inter-action between them and the pond. Moreover, with reference to sun and rain, there is but little that can be done by the farmer, except in a negative way by shading his pond. The heat and light of the sun exert an influence on nearly all units of the system; sunlight dries out the soil, heats the water and influences its capacity for holding gases in solution, provides the chlorophyl-bearing plants and photosynthetic bacteria with energy, limits the growth of various other bacteria, and regulates the metabolic rate of all poikolothermic animals--notably fish--via the temperature of the water, as well as the respiratory activities of plants and bacteria.

A second factor, literally straight from Heaven, is the rain, which affects the soil and, more in particular, the water, where it usually lowers the temperature and occasionally increases the turbidity, thus decreasing photosynthesis of submerged plants to a marked degree. (vide Meyer and Heritage 1941 on the difference between photosynthesis of Ceratophyllum in clear and turbid water in Lake Erie.) The rain usually decreases the concentration of the dissolved minerals, while it increases the oxygen content, and often the amount of nitrogenous substances (vide Vaas 1952, on thunderstorms).

Between the air and the eco-system of the pond many interactions can be pointed out, e.g. the exchange of heat between the air and both soil and water, and the exchange of gases dissolved in the water.

As to the water-supply, this factor is in contrast with those already mentioned, highly controllable. The quantity of water can be regulated at will, and its quality can be adjusted by the addition of manure and fertilizers.

The second group, the internal factors, are characterised by the numerous, intricate interactions between soil, water, biota and fish. In fact, it might be held that the entire science of limnology aims at little more than the elucidation of these interactions.

Summarizing, the following picture might be drawn. The climate, and the chemical and physical properties of the pond-soil and of the water, together with the totality of cultural practices carried out by the farmer, form the basic characteristics of the environment. Nature reacts on a given set of conditions by establishing the flora and fauna most suitable. According to their different abilities, the organisms adapt themselves to the seasonal, diurnal and other changes in the environment, while, sometimes helping, sometimes competing with or even ousting one another, occasionally even exerting considerable influence on the environment itself. (Interception of light by water-bloom, precipitation of calcium by algae,

secretion of lethal toxines by flagellates, increase of turbidity by carps, eradication of floating thread-algea by Tilapia etc.)

Since it is the ultimate aim of the fish farmer to provide his fish with an environment that is the most suitable, the specific requirements of the species of fish cultivated in the pond should receive our preferential attention. These requirements pertain to feeding and spawning. Feeding is a continuous process, whereas spawning is only an incidental one. For spawning special techniques are usually resorted to, sometimes in special ponds, although many cultivated fishes cannot be spawned at all in ponds.

The best way of classifying Indonesian freshwater fish ponds will be to inquire how they fulfill the feeding requirements of the fish.

In ponds, fish may subsist on either natural food (the organisms growing in the pond as a result of its own fertility as well as through the addition of manures and fertilizers etc.) or on fodder, added to the pond by the farmer.

It has repeatedly been shown that even the best kinds of fodder cannot be used as a sole food for fish but that a large proportion of natural food should always be present. In Indonesia, bran is almost the only kind added, while in most cases part of it is not directly ingested, but drops to the bottom of the pond, where it acts as a manure. The production of natural food is, therefore, the most important problem and some examples will be given later of biota, planktonic organisms and others living in various types of freshwater ponds, while their relationships to the physical and chemical properties of those ponds will be described. Furthermore some cultural methods utilized to propagate those organisms which will meet the feeding requirements of the cultivated fish in the best way, will be discussed.

DESCRIPTION OF VARIOUS TYPES OF PONDS.

In Indonesia, notably on Java, freshwater ponds are found wherever sufficient water is available, i.e. they are excavated in soils ranging from rich to poor fertility, and they are fed with water ranging from high to low in mineral content, particularly in lime.

Paddy-fields are also used for fish culture, either after the rice has been harvested or while the rice is still on the field, when the fish--principally the common carp--will swim amidst the rice plants.

Since Java is a densely populated island with a heavy rainfall, running water is the usual means of discarding waste products of whatever kind. The fish farmer has learned to use these waters to enrich his pond. Many ponds in the immediate vicinity of villages and towns, and notably those ponds lying within the compounds of large institutions such as hospitals, lunatic asylums, barracks etc., are fed with water, which might be classified as diluted sewage.

The most important fishes cultivated are: 1) Cyprinus carpio L.-common carp, 2) Tilapia mossambica Peters- mudjair, 3) Osteochilus hasselti (C.V.)- nilem, 4) Puntius javanicus (Blkr.)- tawes and Helostoma temmincki C.V. - tambakan.

Trichogaster trichopterus (Pall.)- sepat siam and Osphronemus goramy Lac.- gouramy, are not of sufficient importance to be inserted in this general survey.

The food requirements of these fish are listed below in table I.

Table I Food requirements of the principal fishes cultivated in fresh water ponds in Indonesia

Species	Submerged higher plants	Thread algae	Peri-phyton	Phyto-plankton	Crustaceans Zooplankton	Insects Larvae	Worms
Common carp		XX	X	X	XXX	XXX	XXX
Tambakan		X	XX	XXX	XX		
Mudjair	X	XX	XXX	XXX	X		
Nilem	XX	XX	XXX	XXX	X		
Tawes	XXX	XX	XX	XX			

In this table the main food is indicated by three crosses, accessory food by two, and emergency food by a single cross.

Carp is a bottom-feeder, tawes a vegetable-feeder, tambakan a plankton-feeder, nilem a periphyton-feeder and mudjair subsists on periphyton, plankton and thread-algae.

Except for common carp grown in paddy-fields, monocultures are exceptions and mixed crops are the usual practice. The differences in the diet of the species mentioned explain why various combinations will be successful, especially since tawes, though showing a distinct preference for soft submerged higher plants (Hydrilla) in natural waters, will grow well, feeding on a mixture of thread-algea, periphyton and plankton. (vide Vaas and Sachlan 1952).

All the groups of biota mentioned in the table are far too complex to state their environmental requirements as a group, generally too little is known even for single species of organisms to be able to encourage and propagate them at will. A perusal of the important work of Rohde (1948-50) and Osterlind (1948-50) shows clearly that considerable labour is involved in obtaining limited results, suitable for practical application, even when working with sterile cultures. Many data referring to the physical and chemical properties of the water of Indian ponds and the composition of the existing biota were published in the Annual Reports of the various Fisheries Departments, e.g. the Progress Report of the Madras Rural Piscicultural Scheme, April 1950-March 1951. (S.V. Ganapati, P.I. Chacko, B. Krishnamurti, et al.)

Gonzalves and Joshi (1946) studied seasonal the succession of algae in ponds and found that Cyanophyceae require a high temperature and high concentrations of dissolved minerals and organic matter. Euglena does not require such a high mineral content but prefers organic substances and a high temperature.

Mookerjee and Bhattacharya (1949) studied the cycle $Ca(HCO_3)_2$ + dissolved organic matter Cyanophyceae + Crustaceans carps. They found that rain caused a decrease in the fish production, via a decrease in the preceding links of the chain, whereas manuring with either dung or decomposed plant-parts effected an increase, for the opposite reason. A notable contribution is the recent work of Komarovsky (1952) on the biota of carp ponds in Israel. This author found Protococcales to be favourably influenced by a high concentration of phosphorous and ammonia nitrogen and Euglenineae and Cryptomonadinae to be favoured by organic matter.

In the case of Indonesian ponds a clear distinction can be made between:

a) ponds with a heavy submerged vegetation and adherent periphyton,

b) ponds with a pronounced development of plankton,

c) ponds with a strongly developed bottom fauna.

In the first group of ponds the nilem is the principal fish, in the second the tambakan, and in the third group the common carp.

There are numerous indications in limnological literature that a heavy growth of submerged higher plants is never combined with strongly developed plankton, due to competition for minerals and sunlight. A waterbloom of plankton absorbs too much light, and, sunlight reaching the bottom will be insufficient for the juvenile stages of higher plants, which must begin their development there. (Swingle 1947, also Vaas 1952). In American fish ponds, fertiliser is sprinkled on undesired submerged vegetation and the resulting heavy local growth of phytoplankton shades the plants, and thus ultimately kills them (Swingle l.c.).

Accordingly, the typical "nilem" ponds of West Java are densely overgrown with Hydrilla verticellata, Ceratophyllum submersum and demersum, and Najas falciculata. These plants carry a dense periphyton of epiphytic diatoms (Navicula, Gomphonema, and notably, Cocconeis), small hormogonic blue-green algae etc. Phytoplankton is poorly developed in the clear, transparent water.

A heavy photosynthesis creates a saturation (often even a super-saturation) of dissolved oxygen, and a CO_2 deficiency in the daytime. The nilem--originally a river-fish--needs a high oxygen-tension and could not be caltivated in oxygen-deficient turbid water. Since the buffer-capacity of the majority of these ponds is rather high, an accumulation of CO_2 during the night need not be feared. Frequently such ponds do not receive any manure, especially when the water is already fertile. An example of such ponds is given in No. 1 of table II. In order to utilize the natural food not eaten by the nilem, common carp are often stocked in the same pond as nilem. In the case of the pond described as No. 2 in table II, the natural fertility had been increased by the addition of night soil as well as bran, on account of the heavy crop of nilem and carp. As a result, various Protococcales, such as Scenedesmus, Pandorina, Eudorina and Pediastrum increase in number. On the other hand, there is the group of ponds stocked with tambakan, mudjair and tawes, or mixtures of these three. In this case a well-developed plankton is aimed at. Examples of such ponds are Nos. 3, 4, 5 and 6 of table II. The acidity of the water is determined by the calcium content of the water, together with the CO_2 produced by decomposing kitchen waste, green manure and other kinds of organic matter. Free CO_2 is always present. Dissolved organic substances are often present in high concentrations, while the oxygen tension is often below the saturation-point during the daytime. Cyanophyceae (Oscillatoria, Microcystus) diatoms (Navicula, Gomphonema, Melosira, Synedra), green algae, such as Pandorina, Eudorina and Scenedesmus, Flagellata (Euglena, Phacus), Crustacea (Cyclops, Bosmina, Diaphanosoma) and Rotifera (Brachionus, Polyarthra, Filinia, Keratella) abound in the water. Oligochaetes and Tentipedidae (Chironomus larvae) are often encountered in the mud on the bottom. Submerged higher plants are usually absent. On poor soils the pH can be as low as 6-6½ (pond No. 3). Heavy manuring may sometimes lower the pH of ponds with a fair calcium content, as a result of strong CO_2 production. (pond No. 4). The age-old practice of stirring the water with rods is occasionally used in such ponds (No.4)

as a typical means of fertilising the water and not the soil, thus encouraging the plankton and not the rooted vegetation. (vide Vaas 1952).

The common practice in carp ponds, where carp are often mixed with tawes and tambakan, is a heavy manuring with human excreta or sewage. As it is intended here to encourage the bottom fauna and not the plankton, the bottom should be fertilised and not the water. Production of CO_2 and oxygen absorption is high on the bottom, and, as is shown by examples Nos. 7 and 8 in table II, even at the surface the dissolved oxygen does not reach the saturation point. As is demonstrated by example No. 8, there is sometimes a large difference between the oxygen tension at the surface and on the bottom, although the ponds are rather shallow. The one used in the example was nowhere deeper than 60 cm.

Zooplankton, together with diatoms, Protococcales and often Cyanophyceae is abudant in the water. The surface is often covered with a green film of Euglena viridis or a red one formed by Euglena sanguinea (Nos. 9 and 10). In case of E. sanguinea these films are composed of cysts, containing an increased quantity of haematochrome. When these flagellates are dividing vigorously, they are highly motile, the amount of haematochrome is less and the film may turn green.

Such ponds produce many Tentipedides and Oligochaetae (Dero, Aulophorus, Nais, Pristina and Chaetogaster) feeding on detritus derived from dead plankton, vegetable debris and other organic matter on the bottom of the pond. These organisms are eagerly sought by the carp which by their constant grubbing on the bottom rake up a lot of mud, and add to the turbidity of the water.

An extreme case is given in example 2, where conditions are described as found in an open sewer running in Bandung City, where common carp are cultivated in bamboo cages suspended in a constant flow of heavily polluted sewage. In an earlier paragraph attention has been drawn to this most interesting case of fish culture. As was stated there, practically no organisms were found in the water itself, but Cyanophyceae, Zoogloea ramigera Itz., Sphaerotilus and Beggiatoa were found on the bamboo strips of the cages and an outburst of Oligochaetae and Chironomus larvae on the sand, gravel and mud of the bottom of the sewer. Remains of the latter animals were found in the guts of the carps in enormous quantities. As seen in table II (No. 2), the oxygen tension is low, in fact, it is too low to grow any fish other than the common carp.

Another interesting case of carp culture, based on the presence of human faeces in open sewers, was studied by M. Sachlan in ponds near Djokjakarta. Although most data were unfortunately lost during the war, the following outline can be presented.

These ponds were fed with water from a sewer, straight from the city drains mixed with irrigation water from the neighbouring paddy-fields. When the amount of faecal matter became too large, the inflowing water could be led past the pond. This procedure is essential because the water will acquire a black colour and a strong faecal smell even after mixing with normal water and no oxygen will be found in it. When the sluices to the first pond are not opportunely closed, a heavy mortality will result. The water from pond No. 1 flows into pond No. 2 etc.

In the first pond only bottom dwelling Cyanophyceae were found and hardly anything else. Strong photosynthesis at noon may buoy up patches of threads, seen floating on the surface. In the morning oxygen tensions of about 30% saturation were found.

In the second pond Euglena covered the entire surface and zooplankton abounds in the water. The amount of light is insufficient for phytoplankton.

In the ponds further on were found water-blooms of Anabaena.

It must be borne in mind that even though the use of human excreta is a wide-spread practice in Indonesia, albeit not in such a pronounced form as in the examples mentioned above, it apparently never gave rise to complaints connected with infectious diseases from the consumers of the fish. Just how quickly and thoroughly a fish pond is able to extinguish pathogenic bacteria might be estimated from a perusal of the results of Schaeffer (1940), who investigated a sewage pond at Djakjakarta. (vide also Vaas 1948).

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Table II Survey of Freshwater fish in Indonesia.

Locality	Tasikmalaya	Tjipanas	Awipari (paddy-fields)	Tasikmalaya	Tasikmalaja	Indihiang	Tasikmalaya	Djokjakarta	Bandung	Tjisaat	Bandung (sewer)
Cyanophyceae	xxx	xxx	x	x	xx	x	xxx	x	xxx	x	xxx
Planktonic Diatoms	xx	xx	xx	xxx	x	x	x	xxx		x	
Epiphytic Diatoms	xxx	xxx								x	
Phytoflagel.			xxx	xxx		x	xx	xx	xxx	xxx	x
Protococcal.	xxx	x	xx	xx	xxx	xx	xxx	xxx	xxx	xxx	x
Green Thread Algae.	x					x	x	xx	xx		xx
Crustaceae.	xxx	x	x	xx	xx	xxx	xx	xxx	xx	xxx	
Rotifera.	xx	x	xx	xx	xx	xx	xx	xxx	xx	xxx	x
Tentipedides			xx	xx	x	x	xx	xx	xxx	xx	xxx
Oligochaetes		x	xx	xx	x	x	x	xx	xx	xx	xxx
Fish i)	NC	NCG	T	T	Tw	M	CTNG	CTwT	CM	CMTw	C
Turbidity + Colour ii)	cl	cl	gr	gr	gr	tr	tr	tr	tr	tr	TR
Manure iii)	la		lv	stm	lv		lv la	sew	sew	stm	SEW
Submerged High Plants.	xxx	xxx									
pH	8-8.3	8.7	6.5-6.7	7.1-7.3	7.2	7.3-8.1	7.3-7.6	8.7	8.5	7.2-7.7	7.4-7.5
Acidity	13-23	2.4	13-15	2.3-2.4	1.3	13-18	23-2.8	1.8	20-25	1.1	1.4-1.6
P mgr/l.	0.004	0.035			0.0085	0.04					
NO_3 mgr/l.	23	12	0.1		0	0.2					8
$KMnO_4$ mgr/l.	27	24	45		14	66				20	46
SiO_2 mgr/l.	27	4	9		22	22					144
O_2 % Sat.	100-100	100-100	100	100	100	100	80	100-50		95-60	50-30
mgr/l - CO_2	def.	def.	50	20	15	13-0	40-10	def.	def.	10-9	9
No.	1	2	3	4	5	6	7	8	9	10	11

i) C = common carp; T = tambakan; Tw = tawes; N = nilem; M = mudjair; G = gouramy.

ii) cl = clear; gr = green; br = brown; tr = turbid; TR = very turbid.

iii) la = latrines; lv = green manure, leaves; stm = stable manure; sew = sewage; SEW = sewage in large amounts.

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SOME FACTORS CONTROLLING ALGAL PRODUCTION IN SALT WATER LAGOONS

by

V.K. Pillai[x]

Introduction.

Salt water lagoons adjoining the coastline of India, being subjected to a wide amplitude of certain physical and chemical factors and presenting a pattern which has no similarity to those of the open sea or estuaries, constitute a distinct category of fertile waters. These lagoons can be broadly divided into two types based on differences in the source of water supply and possibly reflected in production capacity - the one receiving salt water from the sea either by overflow or by the opening of the bars during heavy rains and the other, though adjacent to the seashore, being supplied entirely by rain water and percolated water.

General features of algal growth in salt water lagoons.

Whatever be the source of water, the maximum depth observed is only 3 to 4 feet, the usual depth varying from 1 to 2½ feet. The rate of evaporation in these shallow waters is likely to be considerably greater than the inflow of water from the sea, and the salinity will therefore be higher than that in the open ocean. Schuster (1949) points out that the total salinity of the waters in certain Indonesian marine fish ponds having direct connection with the sea varies between 28 to 46 parts per thousand. In India, although some of the lagoons formed during the rainy seasons are connected with the sea for a time, they are cut off from it immediately after the cessation of rains, from which period onwards the rate of evaporation is very high and the salt content shoots up to crystallisation point (Krishna Pillai, 1953a), the lagoons thereafter behaving like salt marshes. During the transformation a succession of new ecological conditions are created in the lagoons.

The usual range of temperature of the waters in the lagoons in the south-eastern parts of India has been observed to be between 29°C to 39°C. This high temperature, coupled with the bright tropical sunlight, encourages very high rates of photosynthesis of plants immediately after the areas are inundated with fresh sea water rich in nutrient salts. In isolated regions, which depend on rain water, a period of inactivity has been observed during which the water is found to be very poor in essential nutrients, and the growth of algae negligibly small. Within a month, however, the algal growth increases, even though the water does not receive

[x]Central Marine Fisheries Research Station, Mandapam, S. India

any addition of nutrients from outside. This change in the growth rate of the algae could only have been brought about by the release into the water of some of the nutrients present in the bottom mud. Since the release of the nutrients is not instantaneous it has to be assumed that the growth of bacteria takes place first and that these slowly act upon the organic matter in the bottom deposits, thus releasing the inorganic nutrients into the water. Before the rains, when the marshes remain static with a thick layer of sodium chloride and other salts over the bottom mud, there is little scope for bacterial activity. Baas Becking (1928) records only about 20 organisms, comprising the various groups of insecta, crustacea, heterotrophic protozoa, autotrophic protozoa, blue-green algae, fungi and bacteria (mostly anaerobic), that can survive in such environments. Most of the organisms may not even be active or may enter the resting phase.

After the first outburst of growth in the lagoons which had connection with the sea, the rate of growth of the algae decreases considerably, as may be seen from Fig. 1, in which the rate of growth of blue-green algae, including diatoms, observed from two sources, has been plotted.

Influence of Salinity.

Table I gives the predominant organisms found in serial collections made from two lagoons near Mandapam. It may be observed that unlike the phenomena occurring in natural marine environments, blue-green algae formed the major element in the lagoon vegetation when the salinity of the water exceeded 40 parts per thousand. Observations revealed the fact that certain forms of algae viz. Spirulina, Oscillatoria etc., did not appear in the subsequent collections and that Phormidium tenue constituted the bulk of the algae. This indicates that in the lagoons there is a specificity of algal association and growth rate under conditions of water which approach the extremes. Furthermore, evidence has been collected (Krishna Pillai 1953b) to show that most of the species of blue-green algae and some of the diatoms listed in Table I can exhibit normal growth even in high salinity conditions ranging up to 60 parts per thousand, while the blue-green alga Phormidium tenue can withstand even higher salinities (100 parts per thousand) provided other essential nutrients like nitrates, phosphates and certain trace elements are available in sufficient quantities in the media.

Significance of Trace Elements.

The sudden fall in the growth rate of the blue-green algae after the initial predominance during lower salinity conditions cannot be entirely attributed to the influence of ordinary salinity. The water becomes deficient at this stage in growth promoting substances essential to the different species. Chemical examination of water from these lagoons discloses that it is lacking in some of the trace elements, while an analysis of the algae themselves shows that they contain appreciable amounts of these elements (Table II). Boron, zinc and iodine are completely absent from the water while the amounts of other trace elements are extremely small compared to the amounts reported to be present in normal sea water. (Harvey, 1945; Black 1952; Krishna Pillai, unpublished data).

All these observations would suggest that as the areas are inundated with new sea water, the organisms which lie dormant in the bottom mud begin to grow, absorbing the nutrients including trace elements from the sea water but as growth advances to a certain stage the water becomes deficient in these materials and there is no more normal growth of the algae.

The role of Copper.

Studies on laboratory culture of the blue-green algae mentioned above bring out another interesting point which accounts for the presence and absence of certain forms of algae in the lagoon waters during different periods. The presence of copper in water, above a concentration of 80 µg per litre, inhibits the growth of Phormidium tenue, while for the healthy growth of Spirulina, Oscillatoria etc. and a few diatoms like Nitzchia vitrea, a certain amount of copper is found to be absolutely essential. The absence or sparseness of Phormidium tenue from the first collections from the lagoons and the subsequent predominance of the species when the copper content of water goes down tallies with the above observation.

Conclusion.

In this paper on the vegetation existing in lagoons in the south-east coasts of India the effects of grazing by fish and other animals have not been taken into account. Further the exact role of the bottom mud in the production cycle in lagoons is as yet only partially understood. Another important aspect will be the enquiry into the sources of supply of essential trace elements to the lagoon waters, since the quantity brought in by sea water is extremely small and will be insufficient for the support of a continuous vegetation. Part of the decaying organisms will, of course, carry into the bottom mud a good deal of the trace elements in an organic form. The question now to be examined is whether, with limited scope for continuous bacterial activity in the bottom mud, the absorbed elements would be released into the water at any time in an available form.

Work on some of these fundamental aspects has been started at the Central Marine Fisheries Research Station, Mandapam. The results so far obtained are encouraging and these may have great practical importance in view of the fish culture potential of the vast areas of saline lagoons.

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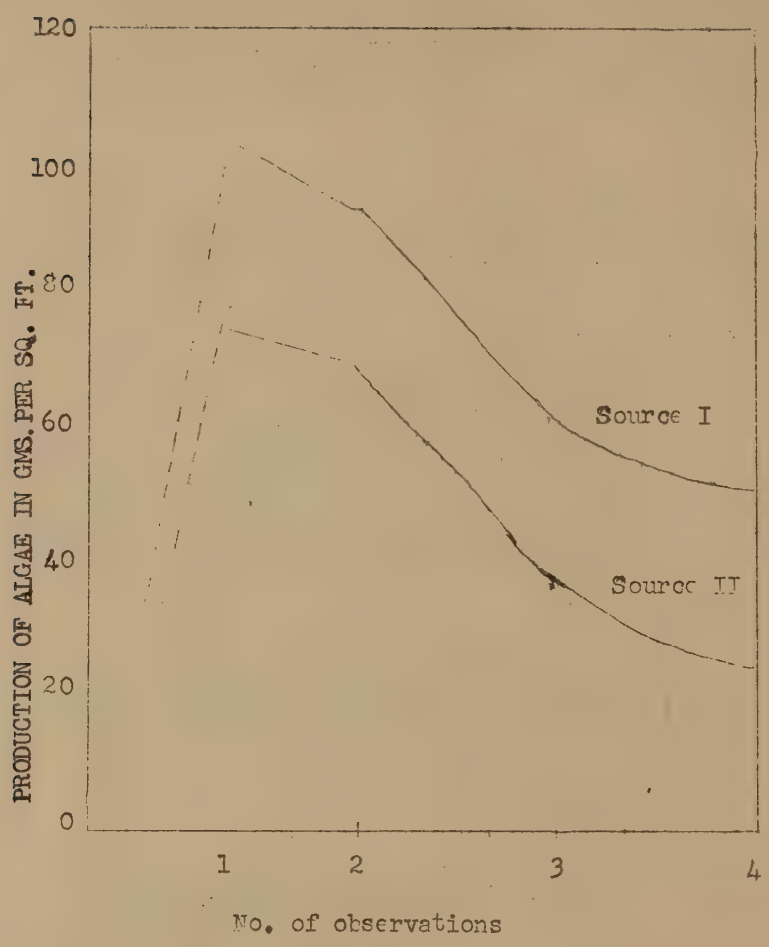
FIGURE I



Observation 1. One week before the connection with the sea was cut off
Observation 2. 3 weeks after the connection with sea was cut off
" 3. 9 " " " " "
" 4. 15 " " " " "

Table I.

Distribution of blue-green algae in lagoons.

Source I			Source II		
Collection 1 when maximum growth was observed. Salinity of water 32.6‰.	Collection 2 (1½ months after). Salinity 76.9‰.	Collection 3 (3 months after). Salinity 201‰.	Collection 1 (when maximum growth was observed) Salinity 36.8‰.	Collection 2 (1½ months after) Salinity 109.0‰.	Collection 3 (3 months after) Salinity 210.8‰.
Blue-green algae					
Oscillatoria sp. 1	Aphanothece sp. (common)	Chroococcus sp. (rare)	Aphanothece sp. (few)	Aphanothece sp. (common)	Oscillatoria sp. (few)
" sp. 2 (abundant)					
Aphanothece sp. (abundant)	Gloeothece sp. (few)	Gomphosphaeria sp. (common)	Chroococcus sp. (common)	Nodularia sp. (few)	Aphanothece sp. (few)
Spirulina sp. (common)	Gomphosphaeria sp. (common)	Merismopedia sp. (common)	Oscillatoria sp. (common)	Oscillatoria sp. (common)	Phormidium tenue (predominant)
Phomidium tenue (few)	Synechococcus sp. (common)	Nodularia sp. (rare)	Nodularia sp. (common)	Phormidium tenue (rare)	
	Spirulina sp. (rare)	Oscillatoria sp. (few)			
	Oscillatoria sp. (few)	Phormidium tenue (abundant)			
	Phormidium tenue (few)				
Diatoms					
Nitzchia vitrea (very common)	Nil	Nitzchia vitrea (few)	Nitzchia vitrea (common)	Nitzchia vitrea (few)	Nil

Table II.

Trace element content of algae and water in salt water lagoons.

		Analysis of algae (expressed as mg. per k.g. dry wt)						Analysis of water (as µ gm / litre)		
		Fe	Mn	Cu	I	B	Zn	Fe	Mn	Cu
Source I	Collection 1	73.0	1.2	12.5	48.6	Trace	5.0	14.0	27.4	31.9
	Collection 2	15.5	0.1	7.3	41.0	Nil	1.0	Trace	--	10.0
	Collection 3	30.8	0.1	Trace	47.6	Nil	1.0	Nil	--	10.0
Source II	Collection 1	55.0	0.4	12.5	24.3	8.0	Nil	8.0	Nil	10.0
	Collection 2	2.0	0.1	Trace	Nil	Nil	Nil	Trace	Trace	Nil
	Collection 3	7.8	0.1	Nil	Nil	Nil	Nil	Trace	Trace	10.0

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HYDROLOGY AND SEASONAL FLUCTUATIONS OF THE PLANKTON IN THE HOOGHLY ESTUARY *

by

N. Dutta,** J.C. Malhotra,** and B.B. Bose**

Contents

SECTION I (By N. Dutta)

1. Introduction — Page 2
2. Physical Features of the Estuary — " 2
3. Tides and their effects — " 2
4. Methods of study — " 3
   a) Centres of Collection — " 3
   b) Gear used — " 4
   c) Nets used — " 4
   d) Periodicity and order of Collections — " 4
   e) Examination of plankton — " 4
      (i) Sedimentation — " 4
      (ii) Enumeration of phyto-plankton — " 4
      (iii) Enumeration of Zooplankton — " 5

SECTION II (By B.B. Bose)

5. Hydrology of the Hooghly estuary(Tables I-V) — " 5

SECTION III (By N. Dutta)

6. Phyto-plankton — " 6

SECTION IV (By J.C. Malhotra)

7. Zooplankton — " 11

SECTION V (By N. Dutta & J.C. Malhotra)

8. General Conclusions — " 17
9. Summary — " 18
10. Acknowledgements — " 18
11. Literature consulted — " 18
12. A list of the phytoplankton met with at the 4 stations on the Hooghly — " 21

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SECTION I

1. INTRODUCTION

Several investigators have demonstrated that an abundance of phyto-plankton is a measure of productivity of a body of water. From August,1949, a team of research workers of the Central Inland Fisheries Research Station of the Government of India, Barrackpore (near Calcutta), began investigations of the seasonal and periodic fluctuations in the plankton of the Hooghly Estuary, between Palta and Diamond Harbour, a stretch of about 63 miles. This estuary is one of the main estuaries of India, and plays an important role not only from the navigational but also from other economic points of view including that of fishery. Since the fluctuations in the production of plankton is governed by the conditions--physical and chemical of the water and those of the general weather,--observations on them were also made simultaneously.

The data regarding the occurrence and availability of plankton during the different seasons of the year, though at present meagre are expected to throw some light on the seasonal fisheries of this estuary which serves as nurseries or feeding grounds for several species of fish.

In this paper are presented the conclusions drawn from the data collected in the first two years of the survey from September, 1949, to August,1951.

2. PHYSICAL FEATURES OF THE ESTUARY (Text Fig. 1)

The mouth of the Hooghly Estuary is wide and deep with its banks tapering into a broad funnel admitting the tides to extend high up in the river, often forming, in the narrower parts of the estuary, what are generally known as bores of an average height of 14-15 ft. The tidal portion of the Hooghly is about 185 miles long, branching off from the river Ganga (Ganges) from a point near Nawadweep-Purbasthali area in the north and emptying itself into the Bay of Bengal, south of the Sagar Islands. The streams that drain into this estuary are Jalangi and Mathbunga on the left bank and Pagla, Dwarka, Ajoy, Damodar, Rupnarain, Haldia and Rasulpure on the right bank. None of these has a perennial upland supply of fresh-water, but all the same, when they flow, they bring into the basin of the Hooghly large quantities of coarse sand and silt. "The flood and the ebb-tides play with these silts and sands twice daily, thus making it difficult for these to come out of the river bed, consequently the bed of the river gradually rises with their deposits" (Bose,1948). As a result of silting up of the river-bed, dredging operations are carried out to keep the navigational channel deep enough for the heavy ships to pass through. Dredging is done between Diamond Harbour and the Docks in Calcutta, a distance of about 42 miles.

Though for all practical purposes, the estuarine navigable portion is reckoned to be about 83 miles long from the metropolitan city of Calcutta, officially the 'Eastern Channel Light Vessel', which lies in the sea at a point 122 miles from Calcutta, marks the beginning of navigation in the estuary.

3. TIDES AND THEIR EFFECTS

With the change of seasons, tidal movements in the Hooghly system also change. According to Oag (1939) three distinct tidal seasons have been observed in this estuary, each of about 4 months' duration.

During the rains from July to October, considering the effects of the S.W. Moonsoons first, the flood tides during this period are more or less completely nullified by the freshets and there is a strong predominance of the ebb-tides.

From November to February is the second tidal season. Owing to the banking of fresh-water in the river during the S.W. Monsoons, the strength of the flood tide over the ebb-tide is minimum.

While on the other hand during the 3rd tidal season (March to June), the hot and dry months, especially May-June, the flood tide effects are considerably accentuated over the ebb-tide. This brings out changes in the salinity of the estuary and during dry summer conditions the effects of high salinity in the Hooghly are felt even far above Palta, where the river water is pumped by the Calcutta Water Works. All the year round (except May and June) the effects of higher salinity extend to a few miles below Calcutta.

This estuary is subject to rapid changes by the incoming tides, which create turbulance almost all over its stretch. The estuary is also polluted by industrial and domestic effluents all along its banks within the limits of greater Calcutta. The influence of tides, strong currents and pollution adversely affect the biological and physico-chemical factors responsible for plankton production in the estuary. Biswas (1942) is of the opinion that the conditions for the growth of phytoplankton and other communities in this river are not as favourable as in other flowing waters.

4. METHODS OF STUDY

(a) Centres of Collection - The undermentioned four stations were selected for collecting our data:-

Station No. I - near the Central Inland Fisheries Research Station, situated at the gates of the Palta Water Works about 107 miles north of Sagar Light House. The river here is about 2,000 ft. wide and 39 ft. deep in the middle.

Station No. II - Near Baghbazar in north Calcutta, at about a distance of 13 miles south of Station I. Width of the river here is 500 ft. more than Station No. I. Depth in the middle portion of the river here is about 34 ft.

Station No. III - At Falta, very near the confluence of the River Damodar with the Hooghly. Its distance from Stations I and II is 50 and 37 miles respectively. The river is very much wider here (12,000 ft.). The maximum depth is 22 ft. in some portions and the average is however, only 10 ft. 6 in.

Station No. IV - Near Diamond Harbour about 63 miles from Station I and 50 and 13 miles respectively from Stations II and III. The river here is 15,000 wide, 24 ft. deep on an average and 39 ft. in its deepest portions, is much wider than all the three stations and is rough during the months March to June. Distance of Stations II, III and IV from the Sagar Light House is approx. 94,57 and 44 miles respectively.

These stations were selected mainly for easy accessibility, availability of boats to make collections and of fish in commercial quantities for measurements and other observations.

(b) Gear Used - For want of standard gear and equipment and of a vessel of our own, the methods of making collections were necessarily crude, and water samples were collected only at or near the surface water, both at flood and ebb-tides. In this preliminary survey a large series of qualitative collections were made, which when quantitatively analysed indicated the composition of the plankton populations in its different zones.*

(c) Nets Used - Two types of conical nets, one fine and the other coarse made locally from muslin and organdy cloths, respectively, were used, the frames being made of brass rings 30.5 cms in diameter at the mouth. Length of the nets from the ring at the mouth to the caudal end of the net was 91.5 cms. A galvanized tin bucket of 125 mls. capacity with 1½" diameter was tied at the caudal end of the net to receive the plankton.

The collections were made both at flood and ebb-tides from a stationary boat anchored about 50-60 yards from the left bank of the river. Both the nets were lowered into the surface water simultaneously against the current of water by means of long lines and kept there for 5 minutes to allow the water to filter through. The nets were then pulled up and the collections in the buckets immediately transfered to glass bottles and preserved in 5% formalin.

(d) Periodicity and Order of Collections

Water samples and plankton collections were made weekly both at flood and ebb-tide every Thursday simultaneously at Palta and at one of the out-stations in the following order:

Station	I	-	Station	II
"	I	-	"	IV
"	I	-	"	III
"	I	-	"	IV

Thus at Station I, collections were made weekly, at Station IV once every fortnight, while at Stations II and III the collections were made once every four weeks.

During the period under review 107 collections were made at Station I, 55 at Station IV and 26 each at Stations II and III respectively with each net and at each tide.

(e) Examination of Plankton

(i) Sedimentation - The collections after being brought to the laboratory were allowed to sediment in conical jars for a period of 7 - 10 days and then the upper clear, supernatant water was pipetted off and the residue made to 50 mls. in specimen tubes 6" x 1". The concentrated samples thus obtained were subsequently used, both for Phyto- and Zooplankton counts.

(ii) Enumeration of phyto-plankton - After thoroughly shaking the concentrate sample, an aliquote sub-sample usually a drop was transferred onto a microscopic slide by means of a wide-bored, graduated pipette and examined under a 19 mm. sq. coverslip with 2/3" objective and a 10 X eye-

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* Menon (1931), Allen and Cupp (1935) and Hart (1942) dealt with the plankton of the Madras coast, the Java Seas and the Antarctic respectively in a similar way.

piece, using a mechanical stage, so that every organism under the cover-slip was identified, as nearly as possible and counted. On an average six such replicates were taken and the results computed for 1 ml. of the concentrated sedimented samples.

In the initial stages of our investigations a known quantity of water (usually a litre) was shaken throughly in a kilner jar, of which 40 mls. were centrifuged until samples were ultimately reduced to 5 mls., everytime for examination as before, but this method of collection was given up in view of its unreliable and unrepresentative character.

(iii) Enumeration of Zooplankton

For the qualitative and quantitative examination of zooplankton, an aliquote sub-sample (2 mls.) was taken from the sedimented sample with the help of a graduated wide-mouthed pipette, after thoroughly shaking and ensuring equal distribution of the plankton. This sub-sample was then transferred to a 16 mm. diameter petri dish, a surface area of 625 sq. mm. was marked into 144 more or less equal squares. Then with the help of a microscope (10 X eye-piece and 2/3" objective) the zooplankton elements present in any 6 squares at random were qualitatively enumerated. Three such enumerations were made and averages calculated for 1 ml. of the sediment.

The results given in the tables (XV to XVIII) are the monthly averages for the various organisms present in 1 ml. of the sediment, by calculating the averages for both the nets and the tides.*

(N. DUTTA)

SECTION II

5. HYDROLOGY

The data collected from the four stations from September, 1949, to August, 1951, are summarised in Tables (I to V**)

(a) Temperature - The range of variation in temperature is about 11°C, the maximum being 32°C and the minimum 21°C. November to March may be regarded as the low temperature period, the temperature varying between about 21°C to 26°C, while from August to October the temperature varies between 29°C to 32°C approximately.

(b) Turbidity - It is generally lowest during the three winter months December to February, but goes on steadily increasing until it reaches the maximum during July - August.

(c) Hydrogen-ion Concentration - pH remains practically constant throughout the year. The water seems to have a high buffer capacity, only a slight depression being observed during the monsoon months.

(d) Alkalinity and Chloride - These are also variable. From September, both the alkalinity and chloride go on increasing, reaching maximum values between March and June. Then they show an abrupt fall with the advent of the monsoon.

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* Arrangements for making the collections and sedimentations were attended to by the 2nd author.

** The Tables are available at the IPFC Secretariat for reference.

(e) Dissolved Oxygen - It remains practically constant throughout the year, as may be expected in a fluviatile system, though some increase is observed at lower temperatures during December and January.

(f) Salinity - Table (V) shows the salinity gradient of the Hooghly estuary at different seasons. When represented graphically, it will be seen that the gradient is at its maximum from March to June.

(B.B. BOSE)

SECTION III

6. PHYTO-PLANKTON

Owing to the mingling of waters in the Hooghly system from a large number of tributary streams and to the banking of water during the flood-tides from the Bay of Bengal, the phyto-plankton in the areas surveyed was varied and composite in character. There was a continuous change during the seasons as a result of the changes in the turbidity, salinity and temperature of the water.

The phytoplankton at all the stations consisted mainly of diatoms. Next to the diatoms, green algae were most prominent during certain seasons, especially at Stations I and II, but were conspicuous by their absence in Stations III and IV, except once in Station III, when a few members of this group were recorded in August, 1950. The blue-green algae though present at all the stations, were not so conspicuous as the diatoms and green algae. Some Dinoflagellates were also observed, though mostly at Stations III and IV.

Bacteria and other fungi which form part of the plankton, though they play an exceedingly important part in the economy of aquatic life by the process of nitrification and denitrification, have not been taken into account as in our collections they were only partially retained by our nets.

Altogether 105 forms were observed of which 72 were diatoms, 18 green algae, 9 blue-green algae, 3 Euglinineae and 3 Dinoflagellates.

A list of the most common and recurring forms recorded in the different seasons is given in Table XIV*. The list includes only those forms which have been either generically or specifically identified, the specific identification being tentative in certain cases.

From the data for the total plankton collected in two years (Tables XV to XVII **) reduced to average per net, per tide, per month, it seems that the greatest bulk of phyto-plankton is in the month of January in both 1949-50 and 50-51. The average hauls of plankton bring out great range and remarkable diversity between the four zones surveyed. Phytoplankton as a whole was richer in 1950-51 than in the preceeding year.

Variations and Abundance of Phytoplankton at different Stations during the years 1949-50 and 1950-51

In Table VI averages of the relative abundance of total phyto-plankton and of the three main groups of algae, viz. the diatoms, the green algae and the blue-green algae, at different stations for the two

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* Only a list of the organisms is given here. The complete chart of their frequency is available at the IPFC Secretariat for reference.

** These tables are available at the IPFC Secretariat for reference.

years are given. Euglinineae and the Dinoflagellates have been grouped together as a Residual group. The table throws some light upon the ecological relations of the various groups, showing their relative numbers and their proportion to the total phytoplankton, recorded at different stations.

Forms observed at Stations I and II were more or less of the same quantity, if not of quality. In view of the situation of the two stations far away from the mouth of the estuary, the phyto-plankton consisted mainly of fresh-water forms during all but the high salinity period (May-June), when some brackish-water forms were also found. At stations III and IV which are nearer the mouth of the estuary, marine or brackish water forms predominated, except during the S.W. monsoons, when some freshwater forms were observed. At Station IV, which is near to the mouth of the estuary a large variety of marine forms was observed.

Station III was the poorest in phyto-plankton incidence. The high turbidity of water always prevalent in that region due to the proximity of the confluence of Damodar and the Hooghly Rivers may be responsible for this poverty.

T A B L E VI

Showing the average total Phyto-plankton crop during the year 1949-50 and 50-51 at different stations.

STATIONS	I		II		III		IV		Gross total of each group of phytoplankton by year.	
AVERAGE FOR THE YEAR	1949-50	1950-51	1949-50	1950-51	1949-50	1950-51	1949-50	1950-51	1949-50	1950-51
1. DIATOMS	57,497	122,544	11,740	5,801	3,179	3,912	9,583	15,677	81,999	147,934
2. GREEN ALGAE	10,552	32,780	2,677	729	40	-	-	-	13,269	33,509
3. BLUE GREEN ALGAE	8,986	3,045	434	285	416	290	244	344	10,080	3,964
4. RESIDUAL	159	244	44	4	146	176	747	37	1,096	461
5. GROSS TOTAL PHYTO-PLANKTON FOR YEAR	77,194	158,613	14,895	6,819	3,781	4,378	10,574	16,058	106,444	185,868

Percentage Composition of Phyto-plankton

In considering the percentage composition of the various groups, the entire period September 1949 to August, 1951, has been taken into account. As mentioned in table VI, it may be seen that diatoms predominate in the phytoplankton to the extent of constituting 76.8, 80.8, 86.9 and 94.6 percent of the total quantity at Stations I to IV respectively. The remainder of the crop was made up of 18.3, 15.7 and 0.4% green algae at Stations I to III and none of this at Stations III and IV during 1950-51. Blue-green algae were 5.1, 3.3, 8.3 and 2.2% respectively at Stations I, II, III and IV. The residual group consisting mainly of Euglinineaea and the Dinoflagellates was 0.2, 0.2, 4.0 and 3.0% respectively at Station I to IV.

Periodicity of Some of the Chief Forms

The Bacillariophyceae (diatoms) were among the most numerous in the phyto-plankton at all times. The maximum yield of diatoms was recorded during the winter months from November to February in both the years at Stations I and II. The highest peak was recorded in December, 1949, in the occureence of diatoms (i) Melosira granulata and (ii) M. granulata variety angustissima at Stations I and II, which were the two most dominant species in that year. In January, 1950, they yielded place to green and blue-green algae (Spirogyra, Microcystis and Anabaena), which disappeared completely by the last weak of February, replaced by Thallassiosira marginata.

The same kind of periodicity was again noticed during the winter of 1950, when Nitzschia sp. predominated, the maximum having been touched in the last week of November, 1950. There was a gradual reduction in its number upto January, 1951, when other forms of green algae, such Tetraedron and Spirogyra, out-numbered the diatoms at Station I only. During the rest of the year the decline which followed, continued till the S.W. monsoon which was the leanest.

At Station IV though no such true rhythm in phytoplankton was noticed in any particular season, there was a gradual increase of diatoms in this zone in both the years in the hot, dry season (April - June) but the increase could not be ascribed to any single species. Coscinodiscus Granii, Bacteriastrum, Ditylum Brightwelii, Chaetoceros, Bidulphia and Hemidiscus were the most prominent forms. An appreciable increase in diatoms was also noticed during the highest salinity periods recorded at Station IV - May and June, 1950, and March to June 1951.

The remaining diatoms consisting of Cyclotella, 6-7 species of Coscinodiscus, Synedra, 4 or 5 species of Nitzschia, Pleurosigma and Chaetoceros 9-10 species and some other forms also show a slight, though negligible, influence in determining the seasonal and annual variations in the phyto-plankton.

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* Purdy (1930) in his study on the Illinois River, mentioned the maximum phytoplankton yields during the spring and summer seasons. It should, however, be noted that the temperature of the Illinois River during the spring or summer months approaches the winter temperature of the River Hooghly.

Green Algae

They were conspicuous at stations I and II, absent at stations III and IV, except once at station III during August, 1950, when some forms of this group were observed. The most conspicuous forms of this group were Spirogyra (3 species), Tetraedron and Eudorina, of which the first named was at its maximum in January, 1950, and the second also in January, 1951, at stations I and II respectively. At stations III and IV no green algae were observed. On the whole they were found to be about 4 times more in 1949-50 than 50-51.

Blue-Green Algae

Though relatively less in number and kind than the diatoms and green algae, this group was conspicuous at all stations during the winter months, represented through out the year by Anabaena, Oscillatoria Pharmedium and Spirulina. Merismopedia and Microcystis, though present from January to March, and again from August, 1950, onwards through the winter months, were absent from April to July.

The Blue-Greens as a whole do not seem, according to our records, to be of great importance. Some of the minute forms may have even escaped through the nets. Though generic identity in some cases was difficult, there was never any doubt about their place in the group.

Residual

This group was made up of 3 forms each from the Euglinineae and the Dinoflagellates. Stray specimens of these 2 small groups were met with during different seasons. Members of the former group viz., Euglena and Phacus were never found below station II, whereas members of the latter group, viz., Ceratium and Peridinium sp. were met with during the high salinity period as far high as station No. II, apart from their occurrence in significant numbers at stations III and IV off and on.

Correlation Between Some Hydrographical Factors and Phytoplankton

Low turbidity and low temperature seem to have an indirect relationship with phytoplankton yield, since the former controls the sun-light available, so essential for the development of algae. The algal crop of the River Hooghly was found to be much reduced during the period of the S.W. Monsoons, when high turbidity prevails (Vide tables XV, XVI, XVII and XVIII).* On the other hand according to Smith (1950) "temperature rarely plays a direct role in the acclimatisation of plankton in new localities, but has a very important effect in its acceleration or retardation of growth and reproduction. He states that temperature is probably the limiting factor for the algae restricted to tropics and sub-tropical regions."

The optimum temperature for the growth of diatoms and green algae seems to lie between 21°C - 23°C. On comparing the data in Tables XV, XVI, XVII and XVIII, the water temperature, when considered singly appears to be the most important factor in determining the seasonal periodicity of the plankton.

A quantitative relationship has also been observed between the phyto-plankton yield and the dissolved oxygen content. The period of maximum dissolved oxygen contents corresponded with that of the maximum phyto-plankton yield. (Tables I-V and XV to XVIII).*

* Available in Secretariat

Salinity too appears to have a definite effect on the quality of phyto-plankton. With the increase in salinity during the hot, dry season (May-June) many of the fresh-water forms observed during the preceeding months disappear and their place is taken up by brackish and marine forms.

(N. DUTTA)

SECTION IV

7. ZOOPLANKTON

The zooplankton in the Hooghly estuary consists mostly of fresh and brackish water species. The fresh-water species are washed down from the upper reaches. A few marine forms were also observed at stations III and IV during March to May when the salinity was at its maximum and much higher than at stations I and II. Fresh-water species were predominant at all the stations from July to October when fresh-water conditions prevailed as a result of freshets in the river. Brackish-water species were, however, present throughout the period of observation.

Table VII - Showing average number of Zooplankton

Station	Average Number for the period 1949-50	Average Number for the period 1950-51	Average Number for the two years 1949-51
Station I	17,485	12,304	29,789
Station II	14,043	10,574	25,617
Station III	10,494	7,129	17,623
Station IV	10,311	7,559	17,870

Table VII reveals that the density of the zooplankton decreases as we proceed downstream, from station I to IV, with the increase in turbidity, the maximum turbidity being at station III where the zooplankton density is minimum. Moreover at Stations I and II the zooplankton maximum during November to March is reached when turbidity is the lowest. The same is observed at stations III and IV during the lowest turbidity months from October to January. The higher density of zooplankton at stations III and IV during September, 1950, is also probably associated with lower turbidity. Another Summer maximum (May and June) of much less intensity than the winter one, occurred at stations I and II whereas at stations III and IV it was during June and July.*

PROTOZOA

Protozoa occurred in large numbers in every collection. As observed by Nash (1947), protozoa in the Hooghly estuary show an inverse correlation with salinity and increase in quantity upstream Table VIII. They were most abundant during November to February at all the stations, as the salinity was also low. Amongst these Rhizopoda (Difflugia spp. and Arcella spp.) were the most common. A few Heliozoa, Radiolaria, Foraminifera and Vorticella were also observed during certain months.

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* A large spring plankton bloom in April and May and a smaller plankton bloom in September have been recorded by Nash (1947) in the estuary of the Patuxent River,

Year 1949-50 is from Sept. '49 to Aug. '50 and
1950-51 is from Sept. '50 to Aug. '51.

Table VIII - Showing average number of Protozoa and their percentage in the total Zooplankton in parenthesis.

Station	Average Number for the period 1949-50	Average Number for the period 1950-51	Average Number for the two years 1949-51
Station I	5,554 (31.8)	4,364 (35.5)	9,918 (33.7)
Station II	5,048 (35.9)	5,120 (48.4)	10,168 (42.7)
Station III	5,511 (52.5)	3,564 (49.9)	9,075 (51.2)
Station IV	4,951 (48.0)	4,301 (56.9)	9,252 (52.5)

Table VIII reveals that on an average the protozoa population during 1950-51 was much less than in 1949-50, and that their percentage in the total zooplankton population was higher in 1950-51 than in 1949-50, due to the fact that during 1950-51 the average salinity at all the four stations was much less than in 1949-50.

Rhizopoda - This group of protozoa was the most abudant and formed about 80 to 90 percent of the total protozoan population. Their identification, even to genera was greatly handicaped by the presence of large quantities of silt. Amongst these Difflugia and Arcella spp. were recorded at stations I and II only. Heliozoa were observed only at stations I and II during the months December to June, and a few Radiolaria at stations III and IV. Foraminifera were found at stations III and IV from March to June and upto station I in May. The colonial ciliates represented by Vorticella were found attached to the copepods etc. and were more so from November to March at all the stations.

ROTIFERS

Rotifera, the most characteristic group of fresh-water animals in the zooplankton show inverse correlation with salinity and decrease in quantity downstream (Table IX).

Table IX - Showing average number of ROTIFERS and their percentage in the total Zooplankton in parenthesis

Station	Average Number for the period 1949-50	Average Number for the period 1950-51	Average Number for the two years 1949-51
Station I	961 (5.5)	177 (1.5)	1,138 (3.4)
Station II	278 (2.0)	80 (0.8)	358 (1.4)
Station III	137 (1.3)	6 (0.1)	143 (0.7)
Station IV	18 (0.2)	10 (0.1)	28 (0.2)

They were totally absent at stations III and IV except in the months, July to November, when salinity at these stations was the lowest. At stations I and II they were present in every collection excepting those made in April, May and June, due probably to the increase in salinity. Their maximum was from November to January (Tables XIX and XX), with the density relatively higher at station I.

CLADOCERA

Most of the Cladocera found in the collections were fresh-water forms. As Table (X) shows they decrease in quantity down-stream due probably to the increase in turbidity, and to the fact that the density of green algae, the food of many cladocera, is very poor in turbid waters.

Table X - Showing number of Cladocera and their percentage in the total Zooplankton in parenthesis

Station	Average Number for the period 1949-50	Average Number for the period 1950-51	Average Number for the two years 1949-51
Station I	2,697 (15.4)	1,827 (14.9)	4,524 (15.1)
Station II	476 (3.4)	433 (4.1)	909 (3.7)
Station III	51 (0.5)	12 (0.3)	63 (0.4)
Station IV	175 (1.7)	44 (0.6)	219 (1.2)

They were present in most of the collections at Stations I and II, being abundant from November to February when the temperature, turbidity and salinity were low. They were absent during most of the months at Stations III due probably to high turbidity, and at Station IV they were much less common than at Stations I and II though present during most of the months.

According to Kofoid (1908) the Cladocera are the planktonic organisms of the warmer waters, the temperature of which is 70° F. In the case of the Hooghly Cladocera, the maximum of which occured in January, 1950, at Stations I and II where the water was very little turbid, the temperature of the water ranged between 21.7°C and 21.3°C, which is the equivalent of the temperature mentioned by Kofoid (1908) for the Illinois River. The most common genera were Diaphanosoma, Moina and Bosmina.

The species of the genera Diaphanosoma, Moina and Bosmina were abundant at Station I and common at Station II from November to February, being maximum during January. They were more in 1949-50 than in 1950-51. Their correlation to the hydrological data shows that temperature between 21° to 22°C, accompanied with low turbidity is presumably most favourable for their occurrence.

COPEPODA

Copepoda is the most abundantly represented order of the Entomostraca and formed the bulk of the Zooplankton in all the collections throughout the period of survey. As shown in tables (XV, XVI, XVII and XVIII) the copepod population is at its maximum at minimum turbidity. The fact that they were more during July, 1950, at Stations III and IV than at Stations I and II is most

probably due to the lower turbidity at the former Stations than at the later. Most probably the same correlation holds good for the large percentage of copepods in total zooplankton during 1949-50 than in 1950-51. With the meagre hydrological data such as we have been able to gather it is premature to trace the exact causes for their seasonal and zonal fluctuations.

Table XI - Showing average number of Copepoda and their percentage in the total Zooplankton in parenthesis

Station	Average Number for the period 1949-50	Average Number for the period 1950-51	Average Number for the two years 1949-51
Station I	5,492 (31.4)	3,633 (29.5)	9,125 (30.5)
Station II	6,062 (43.6)	2,964 (28.0)	9,026 (35.5)
Station III	3,637 (34.7)	2,755 (38.9)	6,392 (6,392)
Station IV	4,180 (40.6)	2,359 (31.9)	6,539 (35.9)

The one pronounced effect of fluctuations in salinity to higher grades was that the fresh-water species totally disappeared at Stations III and IV from March to June when the salinity was the highest.

The identifications of these forms was greatly handicaped by the presence of large quantities of silt. In the following description the seasonal fluctuations of most of the important genera are given.

Tables XIX-XXII* show that the members of the marine genera, Acrocalanus, Paracalanus, Labidocera and Pontella were always at stations I and II and a few members of these were present at stations III, and more so at station IV during the high salinity months. (Tables XXI and XXII). The common species were Acrocalanus inermis Sewell, Paracalanus dubia Sewell, Labidocera gangetica Sewell and Pontella andersoni Sewell. Diaptomus species generally D. blanci Guerne and Richard, D.contortus Gurney, D.cinctus Gurney and D. viduus Gurney were present at all the stations during the months of low salinity (July to November) and were at stations I and II till January. Pseudodiaptomus spp. were present throughout at all the stations, being more at stations I and II from December to March; the common species being P.lobipes Gurney. At stations III and IV they were common from December to February, the common species at these stations being P.annandalei Sewell, P.tollingeri Sewell and P.binghami Sewell. P.lobipes was observed up to stations IV during the rainy season. Amongst the Acartiella spp., A. tortaniformis Sewell was present throughout at all the Stations being common at stations I and II from November to June and at stations III and IV from September to March. They were always more at Stations I and II than at stations III and IV. The other member of this group identified was A. major Sewell. A few members of the marine genus Acartia, the most common being A. plumosa T. Scott, were present at stations III and IV during the months of April to June, when the salinity was the highest. The marine genera Oithona, represented by O. brevicornis Sewell was present only at stations III and IV from January to June when the salinity was high. Members of the genus Cyclopina were at all the stations from July to November at stations I and II they were present till March, the common species being C.longifurca Sewell and C. intermedia Sewell.

* Available in Secretariat

In addition to the above, Mesacyclops spp. were present at all the stations from October to December and Laophonte sp. and Stenhelia sp. were recorded in March and April at stations III and IV. Centropages sp. was observed once in June, 1950, at station IV.

NAUPLII

Nauplii, mostly of copepods, were present in considerable numbers throughout the year at stations I, II, and IV and during most of the months at station III. They were maximum at stations I and II from November to March and stations III and IV during November to December. It appears probably that there is an inverse correlation between turbidity and abundance of larval forms. Their abundance at stations I and II from November to March, and at

Table XII - Showing average number of Nauplii and their percentage in the total Zooplankton in parenthesis.

Station	Average Number for the period 1949-50	Average Number for the period 1950-51	Average Number for the two yrs. 1949-51
Station I	1,785 (10.2)	1,421 (11.6)	3,206 (10.9)
Station II	1,256 (8.5)	1,254 (11.9)	2,510 (10.1)
Station III	522 (5.0)	394 (5.6)	916 (5.3)
Station IV	674 (6.5)	202 (2.7)	876 (4.6)

stations III and IV from November to December adds weight to the above assumption, as the turbidity was at its minimum. Moreover, their decrease in numbers downstream (Table XII) is obviously correlated with increased turbidity. The large number at station III during July, 1950, is also probably due to low turbidity.

MOLLUSCS

The young of Lamellibranchs and Gastropods were present in most of the collections at stations I, II and IV, but fewer at station III.

Lamellibranchs - Young ones were present in most of the collections at stations I and II, particularly from November to January, but in stations III and IV they were rare when present.

Gastropods - The young ones were common at stations III and IV from February to May and at stations I and II in November and December and again from February to May.

Table XIII - Showing average number of Molluscs and their percentage in the total Zooplankton in parenthesis

Station	Average Number for the period 1949-50	Average Number for the period 1950-51	Average Number for the two years 1949-51
Station I	416 (2.4)	533 (4.3)	949 (3.3)
Station II	634 (4.5)	544 (5.1)	1,178 (4.8)
Station III	273 (2.6)	253 (3.5)	526 (3.0)
Station IV	136 (1.3)	484 (6.4)	620 (3.8)

Miscellaneous Zooplankton

Amongst these have been included Branchiopods, Ostracoda Decapod larvae, Lucifer spp. Mysids and Sagitta spp. Branchiopods were present in small numbers at stations I and II from February to July and at Stations III and IV from January to July.

Decapod larvae - Decapod larvae were present in small numbers in most of the collections at all stations. Megalopa larvae mostly of Varuna litterrata were very abundant from July to September at all stations.

Lucifer spp. - A few Lucifer spp. were observed at stations I and II from January to March and at stations III and IV from December to April.

Mysids - They were always absent at stations I and II and present in small numbers at stations III and IV only during September and October. The common species was Macropsis orientalis.

Sagitta spp. - These marine forms were found at stations III and IV only from March to May.

General Remarks about Zooplankton

This preliminary account of the zooplankton of the Hooghly estuary seems to reveal a general inverse correlation between turbidity and occurrence of zooplankton.

Protozoa appear to have an inverse correlation with salinity, increasing in quantity with decrease in salinity.

Reproduction in Cladocera appears to be stimulated by a rise in temperature, 21°C to 22°C being the most favourable limit.

(J.C. MALHOTRA)

S E C T I O N V

8. GENERAL CONCLUSIONS

A few tentative, though suggestive, conclusions from this preliminary investigation are as follows:

Three types of plankton, (1) marine (2) fresh-water and (3) brackish-water forms are found in this estuary. Salinity affects the composition and density of the plankton. Fresh water forms are mostly restricted to low salinity zones (Stations I and II), while the marine forms occur mostly in the high salinity areas (Stations III and IV). Brackish water forms were present at all stations; some of them can adapt themselves to a lower salinity and can grow well there.

Phyto-plankton on the whole was observed to be much poorer than the zoo-plankton probably due to the depth and funnel-like shape of the estuary. Day (1951) also observed the same effect on plankton in a similar estuary in South Africa, with regard to its shape and depth. Along with its shape the effect of tides, coupled with the huge amounts of silt and sand particles brought by the tributaries and worked up by the flood and the ebb-tides twice a day have the effect of breaking up a regular distribution of plankton, with the result that in an open and long estuary like this, plankton is usually poor, especially in its middle reaches.*

The seasonal variation and succession in the plankton of this estuary appears to be influenced (1) by the physico-chemical factors viz. temperature, turbidity and salinity etc.,(but there are certain exceptions to this, e.g., no amount of hydrographic change in the water will determine the presence of Megalopa larvae at a time of year, when they do not naturally occur. Megalopa larvae make their appearance in swarms every year only during the months of July to September in the Hooghly estuary).and (2) biological, by changes in the reproductive activity of the different forms. Correlation of these factors becomes difficult, when two or more of these factors are at work simultaneously.

Tables XV to XVIII suggest that the plankton increases with the decrease in turbidity and reaches its maxima during the periods of low temperature and low turbidity, especially the phyto-plankton. In the case of zooplankton there are two maxima in both the low and the high salinity areas, while only one such maximum occurs in the case of phyto-plankton every year. An increase in Zoo-plankton influences the density of phyto-plankton, which serve as food for the former. Moreover, it is noticed that changes in phyto-plankton are much greater and more sudden than the zooplankton. 1950-51 is more rich in plankton than the year 1949-50.

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* Alexander, Southgate and Bassindale (1936) have also made a similar observation in the case of Tees Estuary.

9. SUMMARY

1. The hydrology and seasonal fluctuations in the plankton of the River Hooghly from September, 1949, to August, 1951, were studied.

2. The river shows a wide range of salinity, turbidity and temperature. The salinity is the highest near the mouth and it gradually decreases inwards. The salinity and turbidity in each of the four stations varies during the different parts of the year.

3. The peak periods of the phyto-plankton at stations I and II were during January in both the years. No such maxima were observed at stations III and IV.

4. Zooplankton showed two maxima at all stations. Stations I and II had peaks during November - March and the second in May-June, whereas at III and IV, the maxima were observed during October-January and then in June-July.

5. The density of phyto-plankton was influenced by turbidity.

6. The composition and distribution of plankton was influenced by salinity. Fresh-water forms were observed at stations I and II throughout the year, while marine forms were more at station IV than at station III.

(N. BUTTA AND J.C. MALHOTRA)

10. ACKNOWLEDGEMENTS

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Table XIV (extract)

A LIST OF THE PHYTO-PLANKTON MET WITH
AT THE 4 STATIONS ON THE HOOGHLY

I. DIATOMS

1. Melosira granulata
2. M.granulata var. angustissima
3. Sceletonema costatum
4. Thalassiosira marginata
5. Cyclotella Meneghiniana
6. C. Kutzingiana
7. C. striata
8. Coscinodiscus Granii
9. C. radiatus
10. C. commutatis
11. C. gigas
12. Coscinodiscus 5 spp.
13. Asteromphalus cleaveanus
14. Planktoniella sol
15. Bacillaria paradoxa
16. Actinocyclus Ehrenbergii
17. Corethron hystrix
18. Lauderia sp.
19. Leptocylindrus danicus
20. L. minimus
21. Guinardia sp.
22. Rhizosolenia robusta
23. Rh.Stolterfothii
24. Rh. imbricata
25. Rh. styliformis
26. Rh. alata forma indica
27. Rh. alata forma inermis
28. Bacteriastrum hyalinum
29. B. varians
30. B. elegans
31. Chaetoceros orientals
32. Ch. peruvianus
33. Ch. affinis
34. Ch. curvisetus
35. Eucampia zoodiacus
36. E. cornuta
37. Climacodium sp.
38. Ditylum Brightwellii
39. Triceratium sp.
40. Bidulphia mobiliensis
41. B. sinensis
42. B. rhombus
43. Ceratulina sp.
44. Hemialus sinensis
45. Hemidiscus Hardmannianus
46. Navicula pigmea
47. Navicula sp.
48. Synedra ulna
49. Lithodesmium sp.
50. Rhopalodia gibba
51. Thallasionema nitzschiodes
52. Thallassiothrix longissima
53. Asterionella japanica
54. Gyrosigma sp.
55. Pleurosigma angulatum

56. Pleurosigma sp.
57. Streptotheca sp.
58. Diploneis sp.
59. Pinnularia sp.
60. Amphora sp.
61. Nitzschia vitrea
62. N. seriata
63. N. closterium
64. N. longissima
65. N. sigma
66. Nitzschia sp.
67. Fragillaria intermedia
68. Surirella elegans
69. S. tenera
70. Cymbella cistula
71. Gomphonema sp.
72. Achananthes sp.

II. GREEN ALGAE

1. Volvox sp.
2. Eudorina elegans
3. Tetraedron sp.
4. Ankistrodesmus
5. Pandorina sp.
6. Pediastrum clathratum
7. P. duplex
8. Crucigenia sp.
9. Scenedesmus quadricauda
10. Spirogyra (3 spp.)
11. Tribonema sp.
12. Closterium sp.
13. Cosmarium sp.
14. Coelastrum sp.
15. Mougeota sp.
16. Oocystis sp.
17. Zygnema sp.
18. Selenastrum sp.

III. BLUE GREEN ALGAE

1. Microcystis aeruginosa
2. M. flos-aquae
3. Merismopedia sp.
4. Lyngbya sp.
5. Oscillatoria (3 spp.)
6. Phormedium sp.
7. Spirulina sp.
8. Anabaena sp.
9. Aphanocapsa sp.

IV. EUGLININEAE

1. Phacus sp.
2. Euglena acus
3. E. oxyuris

V. DINOFLAGELLATES

1. Peridinium sp.
2. Ceratium hiurndinella
3. C. tripos

* The frequency statement of these organisms is available for reference at the IPFC Secretariat

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STUDIES ON THE BLUE-GREEN ALGAE IN JAPAN *

by

T. Harada **

The first studies of the blue-green algae in Japan by Dr. Shioiri appeared in 1942. Other workers later proceeded on the same lines and in 1951, Dr. Okuda of Kyoto University as coordinator, S. Nishigaki, O. Ishizawa, National Institute of Agricultural Sciences, C. Konishi, Hokuriku Regional Agricultural Station, T. Hirano, Sikoku Regional Agricultural Station, Dr. Watanabe, Pharmaceutical Research Institute of Tokyo University and members of several prefectural agricultural experimental stations are now engaged on the problem. The following is the outline of the results of the studies made.

Dr. M. Shioiri and S. Nishigaki reported that when paddy soil is filled in the Erlenmeyer flask and kept under water-logged conditions, blue-green algae such as Nostoc and Oscillaria will propagate in several days and when these organisms propagate profusely soil nitrogen increases very much. Further the propagation of blue-green algae is accelerated remarkably by the addition of lime and phosphates and in such cases the nitrogen fixation will amount to about 22.5 kgs. per hectare. They reasoned that while nitrogen loss is going on in the superficial oxidative layer due to oxidation and leaching, nitrogen fixation occurs, under favourable conditions, and the nitrogen component of the algae, if it is put into the reductive layer of soil by such practices as weeding and others, will be converted into ammonia. T. Hirano disclosed that phosphatic fertilizer applied to the paddy field enriches the soil in respect of nitrogen and reasoned that is due to the profuse propagation of algae and other aquatic plants which enrich the soil with carbon and nitrogen.

Dr. S. Mitsui and T. Harada confirmed that the application of quick or slaked lime accelerate the bacterial decomposition of paddy soil organic nitrogen and may replace nitrogenous fertilizer to some extent. Such lime effect can be induced without the diminution of soil fertility if the amount of lime applied is about one and half tons per hectare. They assumed that the reason why soil is not impoverished with successive lime application lies in the fact that by the application of lime the propagation of blue-green algae is accelerated and nitrogen is sufficiently fixed to compensate the loss induced by lime application.

Since 1941, Dr. Watanabe isolated some ten species of blue-green algae from more than six hundred soil samples collected from southern tropical regions. Tolypothrix tenuis from Borneo, Calothrix brevissima from Palau island and Anabaenopsis spp. from Sumatra were found to be

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* This paper was first presented at the Meeting of the Working Party on Fertilizers of the International Rice Commission which took place in Bangkok in September, 1953. It is reproduced as an IPFC contribution in view of its undoubted interest to fish culturists.

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powerful nitrogen fixers. These three species fixed respectively 5.2 mg 3.4 mg 2.1 mg of nitrogen at 25 degree C. when exposed to the sun for two months in 100 cc no-N, culture solutions. Dr. Okuda experimented on the distribution of blue-green algae in Japanese paddy fields. He reported that with a few exceptions, all the paddy soils he examined were inhabited by blue-green algae. Further experiments were carried out on the relation between the soil conditions and algae propagation, clarifying that the soil reaction and the available phosphorus content were the most influential factors controlling the algae propagation.

S. Nishigaki in cooperation with Dr. Watanabe made a pot experiment with the above-mentioned three species of blue-green algae isolated by Dr. Watanabe. He concluded that Tolypothrix had a definitely positive effect on rice plants while no such positive effect was found in the case of Anabaenopsis. It was confirmed that Tolypothrix fixed 22.5 kgs of nitrogen per hectare and the rice plant absorbed about 4.8 kgs of nitrogen more than the control. The considerable amount of nitrogen which was left unabsorbed in the soil was found to be absorbed the next year.

Dr. Okuda, T. Hirano and C. Konishi also report the possibility in inoculating with algae, but the exclusion from the field of Daphnia and Viviparus which devour the algae is essential, not to say of the application of lime and phosphorus. For killing these animals, the new insecticide parathion is very effective when applied to the irrigation water in a proportion of five ppm.

Hirano Konishi confirmed a 15 to 20 per cent yield increase with the algae when cultivated without the addition of nitrogen, and similar inoculation experiments are in progress at several prefectural agricultural experimental stations. The above experiments aim at increasing yield by the propagation of powerful nitrogen fixers. On the other hand, it is also possible to increase the soil nitrogen content by strengthening the indigenous blue-green algae. In Japan the practice has been adopted of applying lime even when the correcting of soil acidity is not necessary and the beneficial effect may be explained by the strengthening of the indigenous blue-green algae.

It is suggested that in southern regions where commercial fertilizer is not easily available or too costly inoculation of the powerful N-fixing algae or strengthening of the indigenous algae may be a means of getting cheap nitrogen.

Last of all it should be added that the beneficial effect of the algae seems to disappear when much nitrogenous fertilizer is applied at one time, as is usually the case in Japan.

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OBSERVATIONS ON THE DISTRIBUTION AND FLUCTUATIONS OF PLANKTONIC LARVAE OFF MANDAPAM[x]

by

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CONTENTS

INTRODUCTION
MATERIAL AND METHODS
ENVIRONMENT
DISTRIBUTION AND FLUCTUATIONS OF LARVAE
(a) Polyzoa
(b) Polychaeta
(c) Echinodermata
(d) Decapoda
(e) Lamellibranchiata
(f) Gastropoda
(g) Other larvae
(h) Total larvae
BREEDING SEASON
SUMMARY
ACKNOWLEDGMENTS
REFERENCES

INTRODUCTION

A few of the important groups of planktonic larvae that occur in our coastal waters have been studied by various investigators who were concerned chiefly with the taxonomic and developmental aspects. Of the contributions, mention may particularly be made of those of Menon (1919), Panikkar (1936, 1938 and 1947) and Nair (1944 and 1950) on Coelenterates; Aiyar (1933 and 1935) on Polychaetes; Menon (1933, 1937, 1940, 1949 and 1951) and Prasad & Tampi (1953) on Decapods and Alikunhi & Aiyar (1942 and 1943) and Alikunhi (1944a, 1944b and 1950) on Stomatopods. In their general accounts of the plankton Menon (1931), Aiyar, Menon & Menon (1936), Bal & Pradhan (1945 and 1952), Menon (1945), Chacko (1950), George (1953) and Prasad (1953) have made brief remarks about the seasonal distribution of larval forms off Madras, Bombay, Trivandrum, Krusadai, Calicut and Mandapam. But no attempt has so far been made to study in detail the fluctuations in intensity, distribution and composition of the planktonic larval fauna. The present paper is an effort to provide some preliminary information on these aspects of the problem and should be considered essentially as a part of the author's work on the general plankton characteristics of the Mandapam area. It should

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also be mentioned that this report is not meant as an inventory of the innumerable species of larvae that occur in our plankton and the scope has been very much restricted to a general treatment of the distribution and fluctuations of the planktonic larvae off Mandapam.

MATERIAL AND METHODS

The material on which the present findings are based included larval forms obtained from regular plankton samples collected from the inshore waters off Mandapam. The observations extended from January,1950,to December,1952,in the Gulf of Manaar (except for a break during May-June,1951,when unfortunately the collections were interrupted and in April,1952,only one sample could be obtained) and from May,1951,to April,1953,in the Palk Bay.

The method of collection of plankton samples and enumeration of the larvae has been the one followed in this institution (vide Prasad et al., 1952). The number of larvae has been expressed in terms of 1 cc. of the standardized sample.

ENVIRONMENT

The environment in which these observations were made is a shallow-watered area, depth not exceeding about three fathoms with a rich fauna and extensive coral reefs.

The area is exposed to the two prevailing monsoons but the rainfall during the southwest is negligible. The data relating to the rainfall are given in Table 1. Although the southwest monsoon does not contribute much to the annual rainfall of this region it has considerable influence on the waters of the Gulf of Manaar. Extremely turbulent conditions set in May and this continues sometimes even up to August. During this period the drift of water in this area is from south to north and is particularly strong through the Pamban Pass reaching sometimes a velocity of 7 to 8 knots. On the contrary at this time the waters of the Palk Bay are calm. With the onset of the northeast Trade winds, generally sometime during September, conditions are almost exactly opposite to those mentioned above. The Gulf of Manaar becomes comparatively calm, the direction of the drift of water is reversed, turbulent conditions prevail in the Palk Bay, and then the northeast monsoon, the rain-bearing monsoon for this area, breaks in.

Fluctuations in the surface temperature of the sea water of the Gulf of Manaar show a double oscillation in the course of the year. Starting from a minimum in January the temperature rises steadily until April when it reaches the maximum. From May the temperature registers a fall. This lowering of the surface temperature of the coastal waters may be purely due to the strong wind causing a high rate of evaporation. There is again an increase in the surface temperature, but not reaching the same level as that of April, sometime during August-October, the exact month varying slightly from year to year. The time when this secondary peak is reached usually marks the end of the southwest monsoon and the slight increase in the surface temperature may be due to the dying down of the strong wind and consequent reduction in the rate of evaporation. The temperature again falls for a second time with the onset of the northeast monsoon when the sun is at its maximum southern declination. During 1950-1952 the lowest temperature (24.00°C) was recorded in January,1950,and the highest (31.50°C) in April of the same year. The difference between the lowest and the highest mean monthly temperatures for the three year period is 5.32°C, but the range was

5.20°C in 1950, 3.95°C in 1951 and 4.43°C in 1952 (Table 2). It is highly unfortunate that regular records of surface temperature of the Palk Bay waters could not be maintained but the data available suggest that the surface temperature here is slightly of a lower order than that of the Gulf of Manaar.

A regular seasonal cycle in the salinity of the surface waters of the areas under consideration has been observed. In the Gulf of Manaar as well as in the Palk Bay the salinity is low in January, increases gradually and remains high until the middle of November, then there is a decrease, presumably an effect of the northeast monsoon, and the lowest values are often recorded in December (Table 2). With slight variations in the actual values and the exact period of occurrence of the highest and lowest salinities, the general cycle indicated above repeats itself. Thus May to about the middle of November can be regarded as the high salinity period and from late November to April the low salinity period. The annual range of salinity in the Gulf of Manaar varied from 6.92 o/oo to 9.00 o/oo during 1950-1952, whereas in the Palk Bay it was 6.64 o/oo in 1951 (May to December) and 8.80 o/oo in 1952. The greatest difference between the maximum and minimum in both the areas was in 1952.

DISTRIBUTION AND FLUCTUATIONS OF LARVAE.

A wide variety of larvae, in varying intensities is seen almost throughout the year in the coastal waters of this area and, of the innumerable species, many have not been correctly identified. While studying the general characteristics of the plankton of the coastal waters systematic records were maintained of the larval forms occurring in the plankton. The distribution and fluctuations of the following groups, Polyzoans, Polychaetes, Echinoderms, Decapods, Lamellibranchs and Gastropods, larvae of which form the dominant elements, have been dealt with somewhat in detail. Those of the other larval forms only brief references have been made under "Other larvae". These minor groups have been pooled together for purposes of computing their percentage and average number in the larval stock. Fish larvae, which will form the subject matter of a separate paper to be published from this institution, have been excluded from this report.

(a) Polyzoa:

Cyphonautes larvae occurred both in the Gulf of Manaar and the Palk Bay, but often in greater numbers in the Gulf of Manaar, during several months of the year. There were two distinct types (Figs. 1A and 1B). Of these type A, were more abundant and the two common encrusting Polyzoans recorded in this area are Thalamporella rozieri and Membranipora sp.

Great variations were noticed in the occurrence of these in the same area from year to year and also between the areas during the same year. Thus, in the Gulf of Manaar the Cyphonautes larvae showed distinct peaks during May, September-October and December-January. There was an unusual increase in their number in December, 1952. During the three years of this investigation Cyphonautes larvae were always at a minimum in February-April. Occasionally they were noticed to be scarce in other months, too (Fig. 2). Kuriyan (1952) observed that T. razieri, and Membranipora sp. were important polyzoans attaching to the 'monthly collectors'. While mainly restricted to the monsoon months, their appearance in other seasons were not uncommon and he adds: "The breeding season is generally confined to the periods of monsoon". In the Palk Bay the pattern of distribution was strikingly different from that of the Gulf of Manaar. During the period May, 1951, to April, 1952, Cyphonautes were

very poorly represented, whereas in the following twelve months they showed two distinct peaks, one in August and the other in December. Except for the months August and December, 1952, and January, 1953, the larvae were either completely absent or occurred only in insignificant numbers (Fig. 2).

In the Gulf of Manaar Cyphonautes once constituted as much as 75 per cent of all the larvae included in this study and the percentage varied from 0 to 75 (Table 3). The maximum percentage was in 1952 and the minimum in 1950 (Table 4). The average number of Cyphonautes for a year also showed marked variations and on an average there were 13.2, 10.4 and 41.2 larvae for 1950, 1951 and 1952 respectively (Table 5). As already mentioned these larvae were not so abundant in the Palk Bay as in the Gulf of Manaar and as such constituted only a relatively smaller percentage of the larval population. From May, 1951, to April, 1953, their percentage fluctuated from 0. to 35.5 and highest was in January, 1953, (Table 6). On a twelve month basis the percentages were 0.4 and 5.2 during May, 1951, to April, 1953, (Table 7). The average number of Cyphonautes for these two periods is shown in Table 8.

(b) Polychaeta:

The various polychaeto larvae that occur commonly in our waters are fairly well-known due to the fundamental work of Aiyar (1953). During the course of the present investigation several polychaete larvae were encountered in the plankton throughout the year in both areas but in distribution they differed widely. Larvae belonging to the families Polynoidae, Nereidae, Eunicidae, Spionidae, Owenidae, Chaetopteridae, Terebellidae and Sabellaridae were usually represented in the collections.

Polynoid larvae were noticed in the plankton of the Gulf of Manaar in February, May and November; the larvae of Nereids from October to December in the Gulf of Manaar, May to August and again in greater numbers during October-November in the Palk Bay. In the Gulf of Manaar as well as the Palk Bay, Eunicid larvae were often seen during February to April. Larval spionids were extremely common. From February to September, with a maximum in May, they occurred in the Gulf of Manaar and in the Palk Bay during May to August and November with a maximum in August. The typical Mitraria larvae of Owenia fusiformis Delle Chiaje were present in both areas but in greater numbers in the Palk Bay where they occurred during May to August and November, with a maximum in June. In the Gulf of Manaar, on the other hand, they were noticed from January to March, August and November-December with no indications of definite maximal periods. Among the Chaetopterids the only one seen in this locality was the larvae of Phyllochaetopterus gleoti Crossland, but the season of occurrence was observed to be short and somewhat irregular. They were seen in the Gulf of Manaar during January and November with a maximum in January and in the Palk Bay in the months of February, May and September, their largest number being usually in May. Larval and post-larval stages of the Terebellid, Loimia medusa Savigny were often seen during several months (January to April, July, August and October to December) in the Gulf of Manaar, whereas in the Palk Bay they occurred from April to August and again in October-November. In the Gulf of Manaar they showed two maxima, February-April and July-August but in the Palk Bay there was only a single maximum, sometime in June-August. During January, April-May, July and October larvae of Sabellaria sp. occurred in the plankton of Gulf of Manaar with the largest number in May. They were recorded in the Palk Bay during June, August-November, their peak falling sometime during August-September. Occasionally larvae of the Syllid, Autolytus orientalis

willey were also encountered in the plankton particularly in August in the Gulf of Manaar.

The left half of Fig. 3 shows the monthly average number of polychaete larvae for 1950-1952 in the Gulf of Manaar. In 1950 between January and September their average varied from 5 to 10, then there was a slight increase in October followed by an abrupt fall. The distribution in the subsequent year was slightly different, showing a minimum during January, completely absent in December, at a low level during March, April and July to September and two maxima, one in February and the second in November. Polychaete larvae in 1952 showed the maximum in January, then there was a gradual decline in their number (being completely absent in June and October) and from October their number increased. Thus, considerable variations were observed in the distribution from year to year but they were almost at a low level during June to September throughout.

Vagaries in the distribution were noticed in the Palk Bay also. As Fig. 3 shows they were at a maximum in October,1951,and May,1952. During the period of this study their number was low in September, January and February and there were minor peaks in August,1951,and 1952,and April,1953.

Aiyar (1933) in his detailed study of polychaete larvae of the Madras plankton recorded the seasonal occurrence of the larvae of Polyniods, Phyllodocids, Alciopids, Nereids, Nephthyds, Eunicids, Capitellids and Mitraria larvae. Most of these were present all through the year except those of Chaetosphaerids (for 8 months), Chaetopterids (for 7 months) and Terebellids (for 11 months). But they all showed distinct intensive period or periods. Considering the stock of polychaete larvae Aiyar observed that November to March were the crowded months.

In the Gulf of Manaar the percentage of polychaete larvae varied from 0 to 18.7. Except for November,1951,and December,1952, these larvae were present in all the months (Table 3.). Comparing the percentages of these for the three years it will be noticed that there were no very great changes, the larvae contributing from 2.7 to 4.3 per cent of all the larvae (Table 4). Table 5 shows the average number of polychaete larvae for 1950-1952. The percentage of these larvae was slightly higher in the Palk Bay. On the average there were 7.5 to 8.4 larvae and constituted between 4.3 to 5.9 percent (Tables 7 and 8). The percentage from month to month varied from 0 to 29.4 (Table 6). An interesting feature about the polychaete larval stock in these areas was that their percentage did not show violent fluctuations from year to year.

(c) Echinodermata:

Our knowledge of the echinoderm larvae of the Indian waters is meagre. Such larval types as Auricularia, Bipinnaria, Echinopluteus, and Ophiopluteus were usually present in the plankton but Ophioplutei always predominated and as much as 94 per cent of all echinoderm larvae known from this area was once observed to be ophiuroid larvae. Thorson (1946) observed that: "The ophiuroid larvae dominate entirely among the Echinoderm larvae in the Sound. The larvae of Ophiura robusta and Amphiura filiformis alone constitute no less than 82 per cent of all the Echinoderm larvae known from the area in question." The ophiuroid larvae were present during several months of the year, whereas the other types seemed to have a rather much restricted season.

The larvae of ophiuroids were present practically in all months and invariably reached the maximum in May. The next common echinoderm larvae were the Bipinnaria which appeared during March, April and July-September with a maximum in September in the Gulf of Manaar. They were noticed in the plankton of the Palk Bay only in June. Auricularia were present during February to April and July in the Gulf of Manaar plankton and were very few in number. Similarly a few specimens of Auricularia were obtained from the Palk Bay during the months of February, March, May and July. Echinoplutei were comparatively rare in the plankton samples collected so far and a few specimens were seen in April and October.

In the Gulf of Manaar the echioderm larvae showed two distinct maxima one in May and the other in September (except in 1952 when the peak was in November). In all the three years they showed the same minimal period, June to August. Their number was relatively low in December to January, too (Fig. 4). The occurrence of echinoderm larvae seemed to be somewhat similar in the Palk Bay also, with two maxima one in June or July, then a decline followed by a second peak in November. The number decreased again and reached a minimum in December or January (Fig. 4). Despite minor variations in the exact time of maxima and minima the echinoderm larvae showed two distinct maxima, one during the summer months and the other during the autumn.

From the foregoing observations it appears as though that among the echinoderms the intensity of spawning reaches a maximum during the summer months and in some groups there may be a second but less intense spawning activity during the autumn. The ophiuroids seem to have a prolonged spawning season extending over several months but there again the peak spawning was in May.

Echinoderm larvae constituted annually only about a maximum of 2.6 per cent of all the larvae, the percentage fluctuated from 1.9 to 2.6 in the Gulf of Manaar and 1.9 to 2.0 in the Palk Bay (Tables 4 and 7). On an average there were 6.1, 2.1 and 3.3 in the Gulf of Manaar and 2.8 and 3.3 in the Palk Bay during the years covering this investigation (vide Tables 5 and 8). As is only to be expected the percentage of larvae present from month to month showed considerable fluctuations in both the areas, ranging from 0 to 26.4 in the Gulf of Manaar (Table 3) and 0 to 25.1 in the Palk Bay (Table 6). The highest percentage in the Gulf was in September, 1950, whereas in the Palk Bay it was in June, 1952.

(d) Decapoda:

The most important single group of planktonic invertebrate larva was decapod. There is a variety of forms and different developmental stages that occur in the plankton and our present knowledge of the various species is mainly due to the series of contributions by Menon (1933, 1937, 1940, 1949 and 1951). In varying numbers they were found throughout the year in the environs of Mandapam and on certain days in enormous numbers.

Larvae of Portunids, Xanthids, Grapsids, Procellanids, Alpheids, Penaeids and Palinuridae were generally found in the plankton of the Gulf of Manaar and the Palk Bay. Zoeae of certain species of crabs such as Neptunus pelagicus (Linnaeus) were seen in this area during many months of the year, whereas Phyllosoma larvae of Panulirus ornatus (?) Fabricius and Thenus orientalis Milne-Edwards were generally found during February-March and occasionally in June.

Figure 5 shows the distribution of decapod larvae in the Gulf of Manaar and the Palk Bay. During the years 1950-1952 the general trend showed good similarity in the Gulf of Manaar. January to June may be considered as the season when their number was usually at a high level (maximum in March) and from June these larvae become relatively scarce, July to October being somewhat the minimal period and again in November there was an increase which led to the maximal period of January to June. The fluctuations in the decapod larval population of the Palk Bay were different from those of the Gulf of Manaar. In 1951 the decapod larval population gradually increased from a low level in May to high level by September and remained high up to November when it registered a decline reaching a minimum in June,1952. Again from June,1952,there was steady rise which resulted in September a population about three times that of September,1951,and succeeded by a sudden, marked decrease ultimately reaching a minimum by February,1953. Thus, while in the Palk Bay the greatest concentrations of these larvae were during July to November with the maximum in September, in the Gulf of Manaar the population was low from July to October and high during the period January or February to May or June with the maximum in March (Fig. 5).

The percentage of decapod larvae present in the plankton samples from month to month varied considerably, the lowest in the Gulf of Manaar being 1.0 per cent in October,1950,and the highest in December,1951,of 79.1 per cent (Table 3). Annually they showed variations and for the three years the percentages were 10.5 in 1950, 56.6 in 1951 and 24.1 in 1952 and on an average there were 24.8, 64.4 and 36.3 larvae for these years (Tables 4 and 5). In the Palk Bay similar fluctuations were noticed, the lowest monthly percentage of 7.3 was in March,1951,and the highest (87.5) in October 1952 (Table 6). Their percentage on a twelve month period commencing from May,1951,was 26.1 and during the next twelve month period ending with April,1953,it was 35.4 and on an average there were 36.9 and 62.0 decapod larvae during these two periods (Table 7 and 8).

(c) Lamellibranchiata:

Another important group of larvae that occur in the plankton throughout the year was the Lamellibranch. The larvae of following Lamellibranchs were identified.

Ostrea cuculata Born, the Rock oyster of which the larvae were common in both the areas from November to March. While these larvae of the Rock oysters were found abundantly in the Gulf of Manaar and the Palk Bay, the larvae of the Backwater oyster, Ostrea madrasensis Preston were relatively scarce and have so far been observed only in the Palk Bay during December-January. The larvae of Pteria sp., were abundant from December to March and appearing a little later in the year by about April were the larvae of Donax sp., which were particularly abundant in the Palk Bay. The larvae of Pinna sp., were not as common as the others mentioned above and occurred in small numbers from November to March. Larvae of Modiola sp., Solen sp., Teredo sp., Spisula sp., and Tellina sp., all occurred in varying numbers both in the Gulf of Manaar and in the Palk Bay.

The Lamellibranch larval stock invariably showed two maxima in the Gulf of Manaar, one during the early part of the year and the second towards the end. Thus, in 1950 the two important peaks fell in April and October with a third minor peak during January. The number of larvae decreased steadily from April and

reached a minimum during July. In the following year also there was a peak in October but no data are available for May-June. The distribution in 1952 was entirely different from that of the preceding years. In January the number of Lamellibranch larvae was low as in 1951, but in February there was a sudden increase followed by a steady fall, and from then on these larvae were comparatively few and there was no subsequent maximum observed. Certain features were common in all the three years i.e., during the months of June to September and in December the Lamellibranch larval population was at a relatively low level (Fig. 6). Striking similarity in the distribution pattern of Lamellibranch larvae in the Palk Bay was noticed during the course of this investigation. The right half of the Fig. 6 shows a distinct peak in March, 1952 and 1953, although in March, 1952, there were about four times the number of larvae as in March, 1953. During the other months of the year Lamellibranch larvae occurred in relatively small numbers. This distribution seems to be very much similar to that observed in the Gulf of Manaar during 1952 except in the exact time of occurrence of the single peak, being February in the Gulf of Manaar and March in the Palk Bay.

The percentage of Lamellibranch larvae occurring in the different months in the Gulf of Manaar varied from 2.6 in January, 1951, to 59.3 in January, 1950, (Table 3), whereas they contributed to 43.3 per cent, 9.8 per cent and 23.1 per cent of all larvae for 1950, 1951 and 1952 respectively (Table 4). The average number of larvae fluctuated very strikingly from year to year being the minimum in 1951 and maximum in 1950 (Table 5) but the larvae were present in all the months. Except in December, 1951, and October, 1952, Lamellibranch larvae were present in the Palk Bay and their percentage varied from 1.8 in January, 1952, to 64.3 in March, 1952, (Table 6). For the two twelve months' periods commencing from May, 1951, their percentages were 34.4 and 13.8 (Table 7) and for the same period on an average there were 48.7 and 24.4 larvae of Lamellibranchs (Table 8).

(f) Gastropods:

Just as in the case of Lamellibranch larvae, several species of Gastropod larvae too occurred in the plankton almost throughout the year in the areas under consideration (Fig. 7). In the Gulf of Manaar the number of larvae was generally at a low level in January, but it showed a gradual increase with a peak sometime in April (the value for April, 1952, is based on a single observation). Following this peak there was a decline and generally during May to June they were few. In August, 1950 and 1951, there was an abrupt increase in their number and a subsequent fall. Throughout 1952 the Gastropod larvae were comparatively few and particularly in August there was no marked increase in their number. In the Palk Bay also these larvae were relatively scarce in January. From then on they showed a steady rise resulting in a peak sometime during March-April. This was followed by a decline and from June to October larval Gastropods were at a low ebb. Two peaks, one in November, 1951, and another in December, 1952, were also recorded (Fig. 7).

Sometimes as much as 73.00 per cent of all the larvae may be those of Gastropods and their percentage went down as low as 3.2 (excluding the single observation made in April, 1952) at other times (Table 3). 33.8, 18.1 and 19.3 per cent of all the larvae were Gastropods during 1950, 1951 and 1952 respectively (Table 4). The average number fluctuated from 20.6 in 1951 to 80.2 in 1950 (Table 5). Similarly in the Palk Bay their percentage varied from 6.5 in December, 1951, to 72.2 in April, 1952, (Table 6). From May, 1951, to April, 1952, they contributed to 30.1 per cent and during the ensuing twelve months (May, 1952, to April, 1953) their percentage was 38.3 (Table 7). The

mean numbers of these larvae for periods of twelve months from May, 1951, to April, 1953, were 42.6 and 67.2 (Table 8). Thus, along with the larvae of Decapods and Lamellibranchs the Gastropod larvae also form an important constituent of the larval population of the local plankton. Since detailed investigations are being carried out in this institution on the various planktonic Gastropod larvae of this locality their seasonal fluctuations are not given here.

(g) Other larvae:

In the foregoing pages a general account of the important groups of larvae which form the major constituents of the planktonic larval population of this area has been given. Besides those already described there are several groups of larval forms which, though sometimes found in appreciable numbers, cannot be considered as regular features or as important members of the plankton off Mandapam.

COELENTERATA: Both in the Gulf of Manaar and the Palk Bay innumerable planula larvae occurred on a few days. Usually they were present in March in the Gulf of Manaar and in the Palk Bay. From the Gulf of Manaar stray specimens of Ceriantherian larvae were also recorded in March, 1951. From April to June, 1952, and April of 1953 Scyphs larvae were found in large numbers in the Palk Bay, particularly in 1952. The same type of larvae were relatively few in the Gulf of Manaar and were collected only on one or two occasions during June, 1952. These brownish cigar-shaped larvae (Fig. 8) probably are of a species of Zoanthella.

PLATYHELMINTHES: Mullers larvae although they occurred on several occasions in the plankton were never observed in large numbers. In the Gulf of Manaar they were noticed in April, May and again in August-September, whereas from the Palk Bay they were collected during February, March, May, July and August.

NEMERTEA: Nemertean larvae, Pilidium, were seen only seldom in this area and stray specimens were seen in March, May and November in the Palk Bay. From this area two or three Nemerteans have been recorded by Gravely (1927a) who identified only one species, Eupolea hemprichi (Ehrenberg). He, however, remarked: "Pilidium larvae have been seen in the plankton".

PHORONIDA: Another larva that did not appear often in the plankton was Actinotrocha. They were seen only once in the Gulf of Manaar during October, 1951, and presumably belong to Phoronis sp., which has been recorded from this area (Gravely, 1927b).

BRACHIOPODA: The larvae of Brachiopods were extremely rare in this locality and so far collected only once in June, 1952, from the Gulf of Manaar. The larva recorded is shown in Fig. 9 and it probably belongs to a species of Lingula.

STOMATOPODA: Several species of Stomatopod larvae particularly Alima of Squilla occurred in this area during March, April, June and September in the Gulf of Manaar and January to March and again in November-December in the Palk Bay. In the Palk Bay, where they were often found in greater numbers, they reached a maximum in January-February.

ENTEROPROCTA: Tornaria larvae were observed in considerable numbers in January, 1950, in the Gulf of Manaar and in October, 1952, in the Palk Bay. More than one type has been observed in this area and full details regarding these have been given by Devanesan and

Varadarajan (1940).

ASCIDIACEA: In small numbers Ascidian 'tadpoles' were found on several occasions in the plankton of both the localities in question. From January to April and November-December they were invariably seen in the Gulf of Manaar but in the Palk Bay they appeared during February to April, June to August and again in October.

The monthly percentage composition of these "Other larvae" varied from 0 to 3.9 in the Gulf of Manaar (Table 3) and from 0 to 4.1 in the Palk Bay (Table 6). During the year 1950, 1951 and 1952 they formed 1.2, 0.3 and 0.5 percentage respectively of all the larvae in the Gulf, while from May, 1951, to April, 1952, the percentage was 1.6 and May, 1952, to April, 1953, it was 1.5 in the Palk Bay (Tables 4 and 7). On an average they formed about 0.5 to 1.3 in the Gulf of Manaar and 1.6 in the Palk Bay (Tables 5 and 8).

(h) Total larvae:

Fluctuations in mean monthly number of the entire larval stock is shown in Fig. 10. Broadly speaking there were two maximal periods separated by a short interval when the larval population is at a low level. The fluctuations further suggest variations from year to year and changes in the intensity of population. Disregarding the finer details, it may said that the greatest number of larval forms were encountered during the first few months of the year particularly February-May the maximum falling in March or April. The decline in the number of larvae following the maximal period continued up to July and generally during the months June-July there are relatively few larvae in the plankton. The fluctuations in the larval population were rather erratic during the second half of the year. Thus, in the Gulf of Manaar in 1950 from August to October there was a fairly large number of larvae, but 1951 during August-September and 1952 from August to November their number was low and the peaks were in October, 1951, and December, 1952. In the Palk Bay the mean number of total larvae increased gradually from May, 1951, reaching a peak in November and then there was a fall to a minimum in January, 1952. The distribution was somewhat different during 1952-53. Commencing with January, 1952, the number of larvae increased reaching a high level in March but in April there was a steep fall and in June it was at its lowest. During the subsequent months there was again a rise culminating in a peak in September. This was succeeded by a decline and again an increase until December. In 1953 the number of total larvae was low once again but the lowest level was in February as against January in the previous year. There was a peak in March, 1953, as in the previous year followed by a fall in number. Thus, while in certain respects there were similarities there are distinct differences, too, between the two areas in the fluctuations of the total larval population. It is also interesting to note that in December, 1952, there was an unusually large number of larvae in the Gulf of Manaar and the Palk Bay which was caused by an increase mostly of Cyphonautes larvae. The general trends may, therefore, be summarised as follows. During January the total number of larvae was usually low but then it increased reaching a peak sometime in February, March or April. Following this there was a marked decline and in June-July planktonic larvae were comparatively few. There was a second increase in larval population which might reach various levels of intensities during August to October. In all the three years the number of larvae in the Gulf of Manaar was low in July and November. Both the areas showed a large number of larvae in December, 1952, (caused by the increase in the number of Cyphonautes) but for which the level was usually low in this month.

BREEDING SEASON.

A question that is often much debated is whether the tropical marine animals, particularly the invertebrates, breed continuously during the whole year. An almost uniform temperature condition and the possibility of a long period of phytoplankton production are causes generally advanced for this assumption. The available information on this question has been summarised by Panikkar and Aiyar (1939), Paul (1942) and Thorson (1946 and 1950). In the brackish-waters of Adyar, Panikkar and Aiyar (1939) observed that some species reproduce equally in all months, others spawning in all months but with definite intensive periods at certain season of the year, still others reproducing during a particular season of the year only and finally those whose breeding season may be restricted to two or more seasons of the year in relation to the rainfall. Paul (1942) classified breeding among the animals along the Madras coast into the four categories: (1) single breeding period not lasting the whole year round (2) continues breeding in all the year round but more active during a certain part of it (3) continuous breeding throughout the year without any special intensity in breeding during any part of it and (4) discontinuous breeding related to phases of the moon. Summing up the results of investigations on the breeding in tropical marine animals Thorson (1950) remarked: "These observations from the tropics show that, although several of the species have a restricted breeding season, this season is on an average much longer than the breeding seasons of species living in temperate seas, and while in temperate seas most species will breed within the same few months which will result in a crowding and a keen competition of the larvae in the plankton, the tropical species breed within such different seasons that their larval stock taken as a whole is more or less equally distributed in the plankton all the year round. Thus, although maxima and minima occur even in the tropical coastal areas, it is easily understood that the conditions for a pelagic planktotrophic larval development are specially favourable there. A long season of phytoplankton production is associated with a long season of larval occurrence in the plankton. The competition among the larvae is more keen than in temperate - not to speak of arctic seas, where all pelagic larvae have to crowd and feed from the plankton during a few, restricted maxima of phytoplankton production."

Judging from the occurrence of larvae in the plankton it may be said that breeding of invertebrates in this area is not always continuous and at the same uniform rate. The types of breeding observed may be broadly classified as follows:

(1) Protracted spawning season extending over several months of the year or the entire year when larval forms are encountered in the plankton but with distinct intensive period or periods.

(2) Single, restricted spawning season.

(3) Discontinuous breeding, the larvae appearing at irregular intervals with intervening periods of quiescence.

No instance of a species reproducing continuously at a uniform rate without distinct, intensive period or periods during any part of the year has been observed so far in this locality. The assumption that "the tropical species breed within such different seasons that their larval stock taken as a whole is more or less equally distributed in the plankton all the year round," does not seem to be true for the area under investigation. A reference to Fig. 10 will convince that there is apparently no uniformity in the distribution of the total planktonic larval population throughout the year.

It exhibits well-defined maxima and minima. Similarly, the various figures of the different groups of larvae presented in the foregoing pages again demonstrate that there is hardly any group which does not show greater concentration in the distribution of larvae in the plankton at some time or other of the year.

It is not the intention of the author to bring in the highly controversial and complex subject - the factors controlling spawning - but one or two points need mention particularly with a view to stimulating interest for further research among the local investigators. For a long time it was believed that temperature is the all important factor controlling the ripening of sex products and subsequent spawning, but of late, evidence has accumulated to show that temperature need not always be the only or the major decisive factor in controlling reproduction, particularly so in tropical areas where the range in fluctuations is comparatively narrow. Here it may be pointed that in attempting to study the effect of temperature on breeding as Thorson (1946) remarked it is necessary to distinguish between "temperatures which allow the animals to ripen their sexual products and temperatures which actually induce the animals to spawn". Other factors such as salinity, availability of food, tide, lunar periodicity etc. have been shown to exert influence on the breeding activity of marine animals. One thing seems quite obvious and that is, it is not a single physical, chemical or biological factor that controls breeding, but these in varying degrees may contribute for a successful reproduction, the requirements varying with species and to some extent individuals. The importance of temperature in spawning has probably been exaggerated and other possible causes have not been properly examined. Wimpenny (as quoted by Lucas, 1949) found the eggs and very young stages of certain zooplankters and fish, usually in large numbers, in the midst of some phytoplankton patches. He suggested that the abundant oxygen supply of such waters may be advantageous to the young. Lucas, in this connection, remarked: "One can also imagine other by-products of such growth to which adaptations might have been developed", obviously referring to the effects of external metabolitics. Devanesan (1942) observed that mackerels along the west coast of India spawn among patches of Noctiluca and remarked: "The spawning mackerels have probably exercised a choice in selecting an area where the inedible Noctiluca abounded for laying their eggs. Fishes feeding on fish-eggs would be loathe to enter an area where the inedible Noctiluca abounded. Thanks to the instinct of the Mackerel spawners, their eggs thus derive protection and have a better chance of hatching....." This, as in the other case recorded by Wimpenny, may be attributable to the effects of ectocrines rather than a careful choice of the spawning area by the mackerels as this necessarily assumes a freedom of choice on the part of the mackerel which it is doubtful whether our present knowledge would admit. Thorson (1946) cited examples in which spawning on large scale sets in simultaneously with a sudden increase in the phytoplankton. He also referred to the observations of Miyazaki "who at Japan induced spawning in males of Ostrea gigas by adding an extract of the green algae Ulva pertusa and a species of Enteromorpha to the water. The same author tried several other spawning stimuli but all without success, and mentions that the extract of 1 mgr wet leaf of Ulva is sufficient to induce spawning. The active substance is soluble in the water and tolerates boiling for 30 or 40 minutes without losing its activity". Thorson concluded: "Thus it is not excluded that an increase in the stock of phytoplankton may induce spawning in marine vertebrates. There seems also to be a possibility that the temperature and the phytoplankton maxima may act together as inducements to spawning".

There is not sufficient basis in the present investigation to draw positive conclusions regarding the relation between larval

maxima and phytoplankton production. The general cycle of phytoplankton production in the Gulf of Manaar may be described as follows. During the years covered by this investigation, although there were minor variations in the exact time of maxima and minima, it was observed that there were sudden outbursts of phytoplankton during January to March predominantly composed of Rhizosolenia alata or R. imbricata. In April the diatoms are relatively low but the Dinophyceae attain a peak. Immediately following this will be the summer bloom in May composed mainly of several species of Chaetoceros, Rhizosolenia, and Pleurosigma, Asterionella japonica, Thalassiothrix frauenfaldii, Thalassionema nitzschioides, Biddulphia sinensis, B. mobiliense, Bacteriastrumvarians, Bacillaria paradoxa etc. In June-July there is an appreciable decimation in the phytoplankton succeeded by an increase reaching a peak sometime between August and November, the exact month in which the highest level reached varying slightly from year to year. This autumn bloom, like the one in summer, is the result of several species of diatoms flowering simultaneously. Thus, there seems to be definite pulses in the production of phytoplankton, the seasons of abundance being January to May and August to November.

Comparing this phytoplankton cycle with the distribution of the various larval groups and the total pelagic larvae of the Gulf of Manaar one finds that there is reason to believe that the periods of larval maxima coincide somewhat with those of abundant phytoplankton production. In the Palk Bay the cycle of phytoplankton production is distinctly different. Starting from a low level in January, the production increases rapidly reaching a peak in May or June. This outburst is caused chiefly by several species of Chaetoceros, Rhizosolenia, Pleurosigma, Nitzschia and Bacteriastrum varians, B. hyalinum, Talassiothrix frauenfeldii, Talassionema nitzschioides, Asterionella japonica, Leptocylindrus minimus etc. Normally this bloom is followed by a slight decrease in the phytoplankton population but once again there is an increase leading to high level in September-October. By November the diatoms show a tendency to decimate but the Dinophyceae are still relatively abundant. During December the area is extremely poor in phytoplankton. As already stated, the planktonic larval stock is low in January and shows an increase, attaining different levels of intensity, during February-May. During June the larvae are scarce but in July they show tendencies to increase and most of the larval groups become less abundant by December. Therefore, it will be noticed that there is a crowding of the planktonic larvae during the seasons when the phytoplankton production is sufficiently high. But it should be added that certain instances of an inverse relation between larval population and phytoplankton has been noticed in the areas under study, particularly so when the phytoplankton production happens to be exceedingly high. Aiyar (1933) in his report on the polychaete larvae of the Madras plankton remarked: "It will be seen that November to March are crowded months and this is the period when the phytoplankton is also abundant." Here again the larval maximum did not coincide with the season when the phytoplankton of the area was at its highest which is between April-July (Ref. Menon, 1931) 2/

A reference in passing may be made about the correlation with temperature. As already mentioned earlier in this report,

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2/ Unfortunately Thorson (1950) has misinterpreted Aiyar (1933) and stated: "In plankton off the Madras coast larvae of polychaetes occurred throughout the year though with a maximum during the season (November to March) with the richest production of phytoplankton (Aiyar, 1933)". According to Aiyar the larval maximum was at a time when the phytoplankton was abundant and not when it was the richest.

regular temperature data were available only for the Gulf of Manaar. The temperature curves show a double oscillation in the course of the year. Similarly the curves for the total larvae also show a bimodality, the peaks of these two curves somewhat coinciding.

The possible effect of the monsoon on the breeding in marine invertebrates of this locality, either direct or indirect, cannot be overlooked. In general it appears that the intensity of spawning is rather low during the months when the monsoon is vigorous and shows a tendency to increase with the weakening of the monsoon and consequent resumption of calm conditions. To put down anything beyond broad generalities a more detailed study is essential. The relations between the phytoplankton production and breeding in marine invertebrates are likely to be specific and, therefore, the study will have to be carried out in terms of relationships between particular species of larvae and phytoplankton. However, from the present preliminary study the author is inclined to believe that the optimum temperature conditions together with the presence of abundant phytoplankton of the proper species (the stimulus may probably be ectocrine of the species concerned) act as the important stimuli for initiating spawning in many marine invertebrates. The problem although complex is one of fundamental importance in understanding marine life. The scope of the present investigation unfortunately does not permit a more detailed discussion of the problem and no doubt a systematic study of breeding in at least some of the common species with particular reference to their food requirements and important environmental factors will throw more light on the subject. Nevertheless, the present investigation has provided reasons to believe that there are still some misconceptions or slightly exaggerated ideas regarding the breeding in marine animals of tropical waters and the problem needs careful study.

SUMMARY.

The paper is based on larvae collected from the coastal waters of the Gulf of Manaar (January, 1950, to December, 1952) and the Palk Bay (May, 1951, to April, 1953) off Mandapam.

A brief account of the environment and data on rainfall, surface temperature and salinity of the areas under investigation has been given.

The distribution and fluctuations in the composition and intensity of the dominant elements of larval population such as Polyzoan, Polychaete, Echinoderm, Decapod, Lamellibranch and Gastropod larvae have been discussed in some detail. The seasonal occurrence of other groups of larvae has been briefly mentioned. Wherever possible information on the season of occurrence, maxima and minima of individual species has also been given.

The percentage composition of the planktonic larval population has shown that Decapods, Lamellibranchs and Gastropods constitute the three important groups. The three together account for more than 60 per cent of all larvae and sometimes as much as 90 per cent. Marked variations in the composition and intensity of the larval stock from year to year especially in the major elements have been noticed. The polychaete and echinoderm larvae show the minimum annual variation.

The distribution of larvae belonging to the different groups treated in this paper has revealed distinct maxima and minima and so also the total larval population. While certain groups have shown similarities in the pattern of distribution others vary from year to year but on the whole it can be said that within an area the general trend is somewhat the same from one year to another. Similarly some groups have similarities in distribution and fluctuations between the two areas but others have exhibited striking differences.

The breeding season of invertebrates in this area has been very briefly discussed and the following three types have been recognized based on the occurrence of larval forms in the plankton: (1) protracted breeding season extending over several months of the year or even the whole year but with distinct intensive period or periods, (2) breeding restricted to some definite part of the year and (3) discontinuous breeding occurring almost throughout the year, breeding taking place at irregular intervals with periods of quiescence in between.

In general the study has indicated that there is possibly a relation between the phytoplankton production and the larval maxima, the latter coinciding somewhat with periods of abundant phytoplankton. However, it has also been noticed that when the production of phytoplankton is exceedingly high there is usually a low larval population. The present findings are not final and this aspect requires careful study. The study has, however, provided reasons to believe that there are still some misconceptions or slightly exaggerated notions regarding breeding of marine invertebrates in tropical areas. The inadequacy of detailed data in the present instance permit only to speak in broad generalities. For a better and proper understanding of the problem a careful study with particular reference to the food requirements of individual species of larvae, their physico-chemical and biological environments is necessary.

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Table 1

Monthly rainfall in inches for the locality

Months	1950	1951	1952	1953
January	2.1	3.8	5.4	0.6
February	1.7	1.1	1.8	1.1
March	2.2	0.3	0.0	0.0
April	1.1	8.4	2.0	1.9
May	0.4	0.4	0.9	-
June	0.0	0.0	0.2	-
July	0.0	0.2	0.8	-
August	1.3	0.0	0.3	-
September	0.0	2.5	0.0	-
October	5.8	1.8	0.4	-
November	8.6	15.3	5.5	-
December	3.0	6.5	0.8	-

Table 2

Mean monthly salinity and surface temperature

Months	Gulf of Manaar						Palk Bay					
	1950		1951		1952		1951		1952		1953	
	S o/oo	Surf. Temp. °C	S o/oo	Surf. Temp. °C	S o/oo	Surf. Temp. °C	S o/oo	Surf. Temp. °C	S o/oo	Surf. Temp. °C	S o/oo	Surf. Temp. °C
Jan.	29.49	24.30	29.10	25.53	29.29	25.19	-	-	28.53	-	25.52	24.85
Feb.	30.33	25.55	30.37	26.07	30.62	26.60	-	-	29.58	-	27.25	24.60
Mar.	30.80	26.89	31.54	27.90	32.40	28.26	-	-	30.88	-	29.98	27.32
Apr.	33.63	29.50	33.08	29.48	32.81	29.62	-	-	32.01	28.25	31.60	29.10
May	36.41	29.10	-	29.32	34.67	28.57	-	-	33.04	-	-	-
June	35.21	27.30	-	27.66	35.27	27.58	-	-	33.75	-	-	-
July	35.77	27.40	35.80	27.72	34.78	28.02	-	-	33.96	26.75	-	-
Aug.	36.34	27.94	35.78	28.80	36.42	28.08	-	-	35.21	27.00	-	-
Sept.	35.84	27.30	36.02	28.88	36.47	28.17	35.76	28.00	35.91	27.60	-	-
Oct.	35.93	27.60	35.99	28.13	36.45	28.26	36.07	28.02	36.39	28.13	-	-
Nov.	32.55	27.65	33.95	27.81	31.77	27.25	33.21	27.53	33.12	25.87	-	-
Dec.	29.44	25.65	29.49	25.97	27.47	25.74	29.43	25.95	27.59	-	-	-

Table 3

Percentage of larvae occurring in different months during 1950-1952. Gulf of Manaar.

Animal groups	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Cyphonautes	1950	2.1	2.6	0.4	0.3	13.7	3.7	12.2	3.4	14.4	7.6	1.9	27.0
	1951	31.0	3.2	0.0	0.8	*	*	2.1	27.0	0.0	27.0	0.0	2.3
	1952	14.4	0.3	0.8	0.0	7.6	16.0	2.1	5.6	0.0	0.0	17.2	75.0
Polychaetes	1950	2.9	3.3	2.4	1.3	3.5	2.5	7.4	2.4	3.1	3.6	0.0	2.7
	1951	0.9	10.6	2.1	3.5	*	*	8.8	5.4	9.5	2.2	11.3	0.0
	1952	18.7	1.9	2.5	10.5	3.8	0.0	8.4	2.8	4.3	0.0	7.6	1.2
Echinoderms	1950	0.2	0.0	0.7	0.4	7.6	1.4	3.0	0.5	26.4	0.2	1.0	5.5
	1951	1.9	3.9	0.6	0.2	*	*	4.3	0.0	15.8	3.1	0.0	1.1
	1952	1.1	2.2	0.4	17.1	9.7	4.2	2.1	0.0	0.0	0.0	7.6	0.8
Decapods	1950	9.6	9.4	15.7	3.4	8.9	21.3	6.3	2.5	3.9	1.0	28.0	29.1
	1951	61.2	49.1	58.9	61.7	*	*	37.8	18.9	42.8	45.1	59.5	79.1
	1952	37.4	19.2	39.6	67.1	31.3	34.0	40.3	37.9	13.9	67.8	27.1	7.4
Lamellibranchs	1950	59.3	23.5	46.8	56.9	44.6	36.5	46.5	17.1	27.9	61.1	36.3	22.5
	1951	2.6	9.1	17.8	7.7	*	*	13.3	10.8	19.0	5.3	11.3	6.1
	1952	8.9	56.7	32.7	5.1	19.0	22.6	17.8	27.5	12.9	18.8	13.7	3.6
Gastropods	1950	25.6	60.3	33.3	37.1	21.5	34.4	22.6	73.0	23.6	25.5	32.6	13.2
	1951	3.2	23.5	20.2	25.2	*	*	33.3	37.8	12.6	15.6	17.0	10.3
	1952	16.3	19.5	23.8	0.0	28.5	19.3	27.2	25.8	68.6	13.3	26.7	11.8
Other larvae	1950	0.3	0.9	0.7	0.6	0.2	0.2	2.0	1.1	0.7	1.0	0.2	0.0
	1951	0.0	0.6	0.4	0.9	*	*	0.4	0.1	0.3	0.7	0.9	1.1
	1952	3.2	0.2	0.2	0.2	0.1	3.9	2.1	0.4	0.1	0.1	0.1	0.2

* No data available.

Table 4

Percentage of larvae occurring during 1950-1952:-

Gulf of Manaar

Animal groups	Year 1950	1951	1952
Cyphonautes	5.6	9.0	27.4
Polychaetes	2.7	4.3	3.4
Echinoderms	2.8	1.9	2.2
Decapods	10.5	56.6	24.1
Lamellibranchs	43.4	9.8	23.1
Gastropods	33.8	18.1	19.3
Other larvae	1.2	0.3	0.5

Table 5

Mean annual number of larvae for 1950-1952:
Gulf of Manaar

Animal groups	Year 1950	1951	1952
Cyphonautes	13.2	10.4	41.2
Polychaetes	6.4	4.9	5.1
Echinoderms	6.6	2.1	3.3
Decapods	24.8	64.4	36.3
Lamellibranchs	102.9	11.1	34.9
Gastropods	80.2	20.6	29.2
Other larvae	1.3	0.8	0.5

Table 6

Percentage of larvae occurring in different months of 1951-53 (May-April). Palk Bay.

Animal groups	Year	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Cyphonautes	1951-1952	0.0	2.6	0.7	0.0	0.5	0.0	0.2	0.0	3.7	1.2	0.0	0.0
	1952-1953	0.4	0.0	3.0	12.5	0.0	0.0	6.9	21.6	35.5	0.5	0.0	0.0
Polychaetes	1951-1952	9.6	29.4	14.0	15.3	4.3	19.1	4.1	9.1	0.0	2.5	0.3	0.8
	1952-1953	10.2	12.0	2.1	8.4	1.9	4.1	2.8	1.0	1.2	0.0	1.9	5.3
Echinoderms	1951-1952	10.9	5.2	6.2	0.3	1.0	2.7	2.9	0.0	0.0	0.9	0.1	1.4
	1952-1953	3.7	25.1	0.8	0.8	0.2	0.0	2.8	0.5	0.4	0.0	0.3	1.8
Decapods	1951-1952	24.6	30.3	36.9	46.2	71.3	46.4	27.3	84.2	67.1	25.2	7.3	14.8
	1952-1953	17.3	37.1	58.5	43.4	86.6	87.5	64.4	9.3	15.6	25.0	22.4	16.1
Lamellibranchs	1951-1952	35.9	18.2	27.3	13.7	9.0	15.9	21.3	0.0	1.8	27.1	64.3	6.7
	1952-1953	7.4	8.0	3.3	13.7	2.4	0.0	5.8	8.7	5.4	45.9	28.3	8.8
Gastropods	1951-1952	18.8	12.1	14.4	21.9	13.3	15.0	43.5	6.5	23.6	42.1	27.0	72.2
	1952-1953	56.9	16.5	30.8	20.8	8.7	8.2	15.4	58.5	41.0	28.5	45.7	67.7
Other larvae	1951-1952	0.2	2.2	0.5	2.6	0.6	0.9	0.7	0.2	3.8	1.0	1.0	4.1
	1952-1953	4.1	1.3	1.5	0.4	0.2	0.2	1.9	0.4	0.9	0.1	1.4	0.3

Table 7

Percentage composition of larval stock in the Palk Bay (May, 1951, to April, 1953).

Animal groups	Period 1951-1952 (May-April)	Period 1952-1953 (May-April)
Cyphonautes	0.4	5.2
Polychaetes	5.9	4.3
Echinoderms	2.0	1.9
Decapods	26.1	35.4
Lamellibranchs	34.4	13.4
Gastropods	30.1	38.3
Other larvae	1.1	1.5

Table 8

Average number of larvae for periods of twleve months from May, 1951, to April, 1953: Palk Bay.

Animal groups	Period 1951-1952 (May-April)	Period 1952-1953 (May-April)
Cyphonautes	0.6	9.1
Polychaetes	8.4	7.5
Echinoderms	2.8	3.3
Decapods	36.9	62.0
Lamellibranchs	48.7	24.4
Gastropods	42.6	67.2
Other larvae	1.6	1.6

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A PRELIMINARY STUDY OF THE PLANKTON OF THE CHILKA LAKE FOR THE YEARS 1950 & 1951.

by

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INTRODUCTION.

Work on the plankton flora and fauna of the Chilka Lake is very meagre. Biswas (1932) has given a taxonomic survey of the algal flora of the lake covering a period of one year. His observations are restricted to the southern and eastern sections of the Lake. Though he mentions diatom collections in the course of his investigations no paper has yet been published giving their taxonomy or their seasonal fluctuations in the Lake.

Annandale and Kemp (1915) in their introduction to the 'Fauna of the Chilka Lake' have observed that no effort to capture and preserve the representatives of microscopic groups such as Protozoa, Rotifera etc., was made. However, Copepods have been comprehensively worked out by Sewell (1924), Amphipods and Isopods by Chilton (1921, 1924), Gastropods and Lamellibranchs by Annandale and Kemp (1916) and Polychaets by Southern (1921).

In the present paper we shall consider the fluctuation of the different planktonic organisms as revealed by regular collections made in the years 1950 and 1951. (We regret to report that the collections for February, 1950, were accidentally lost). The importance of such studies cannot be over-emphasised since these, if continued for a sufficient period, are likely to reveal the relationship between the seasonal abundance of plankton and its effect of the growth and migration of plankton-feeding fishes in the lake. The work is mainly confined to broad, generic aspects of the plankton composition.

Collection of material was made with the help of a townet of bolting silk No. 11 in which 800 litres of water was filtered. Five representative stations, namely, Balugaon, Kaluparaghat, Rambha, Stapara and Arkhakuda were selected in five different corners of the Lake in view of the fact that salinity varies from place to place due to the intermixture of marine and fresh water in different months of the year. The plankton collections were made every fortnight in each of the above localities at 8.00 a.m. and salinity and temperature were also recorded simultaneously. A 4% formalin solution in Chilka water was used for preservation. To find approximate number of various planktonic organisms in each collection, the preserved material was

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treated as follows: 800 litres of sample collected were concentrated to 50 cc. by pouring out the supernatant liquid and out of the concentrated sample, three separate samples each of 0.04 cc. were transferred to the slide through a wide-mouthed measuring pipette (after thoroughly stirring the concentrated sample) and examined. From these readings, calculations per 100 litres were made. The bigger organisms were counted by naked eye and calculated.

HYDROGRAPHY.

The average depth of the Lake is between 4 to 6 feet except at Rambha and Arkhakuda where it is 10 and 16 feet respectively. The bottom in the southern area and the outer channel is sandy and the rest of the lake clayey. The bottom is generally infested with weeds like Halophila ovata, Najas gramminea, Ruppia maritima, Potamogeton pectinatus etc., (Roy, unpublished).

Annandale and Kemp (1915) carried out the hydrographic investigation during the zoological survey of the lake. They recorded their observations, which explain roughly the changes in salinity in the course of one year and their probable causes.

Table 1, figs. 3 & 4 show the salinity for 1950 and 1951 as recorded in the five centres under observation.

BALUGAON AND KALUPARAGHAT show close similarity in fluctuation of salinity due to the fact that both are situated closer to the mouth of the river Daya, which feeds the lake with fresh water. In the year 1950, both have the peaks in the month of June and the lowest fall in September. Up to June there is a gradual rise and in July (the time when flood water must have entered the lake) both register a slight fall. From October there is a gradual rise, which indicates that flood water had stopped coming in and evaporation and the influx of sea water through the mouth of the lake had begun to increase the salinity of the lake.

In 1951, on the other hand, the degree of salinity has continued to be lower than in 1950 up to June and probably it is due to the influence of comparatively heavy floods in 1950 (Table 2). From August to October, the salinity is higher than in 1950 but in November both the centres show lesser salinity than in 1950. The peaks as well as falls vary in both places; at Balugaon the peak is in July and the lowest fall in November, whereas in Kaluparaghat the peak is in June and the fall in October.

In RAMBHA, in the year 1950 there is a gradual rise in salinity from January to July, and August records the highest salinity. In September there is a sharp fall and November shows the lowest fall for the year. In 1951 too the same trend as in 1950 is followed up to August which is also the peak month for the year, though the degree of salinity is less up to July compared with 1950. From September onwards it follows almost the same trend as in 1950.

Rambha being situated in the southernmost corner of the lake, it is likely that the gradual change from higher to lower degree of salinity takes a longer time than at Balugaon and Kaluparaghat; further, the saline water in the north, having been replaced by fresh water, probably finds its way into the Rambha Bay along the bottom, the surface inflow of fresh water of lesser density being warded off continuously by the strong, surface current of the bay caused by steady and continuous breeze from the southwest or south-south-west (Sewell, 1922), helping the maintenance of a higher degree of salinity as

compared with the other two stations; absence of rivulets is also likely to keep up the salinity in high degree as well as for a longer period than in the other two centres.

SATPARA, which is between the lake and the outer channel is more similar to Arkhakuda in salinity variations than any other part of the lake. From January, 1950, there is a sharp rise up to March and up to June only a gradual rise is recorded, June forming the peak month of the year. In July there is a slight fall and in August a sharp fall and from September onwards the fall continues till it reaches the minimum in November.

But in 1951, although the general trend up to June is similar to 1950, salinity maintains a steady level till August which is the peak month of the year and in September it falls to the minimum to rise again gradually up to December.

ARKHAKUDA, which is on the mouth of the lake opening to the sea shows from January, 1950, a very sharp rise, far higher than that recorded in other stations for February, and up to June it rises gradually to form the peak month of the year, the following months up to September registering very sharp fall. It continues to fall till December though in a gradual fashion.

In 1951, similar to Satpara, salinity follows closely the trend of 1950 to reach its peak in August and then to follow a downward trend up to December.

The fact that both Satpara and Arkhakuda have different peaks in the years 1950 and 1951 indicates that the advent of flood was rather late in 1951 than in 1950. Flood level figures in Table 2 bear testimony to the above fact.

Surface temperature in the year 1950 varies from 25°C to 33°C having the peak in June and the minimum in December. In the year 1951 the range is between 25.2°C to 32.8°C, the former being in December and the latter in June (Table 3).

SEASONAL DISTRIBUTION OF PLANKTON

Zooplankton.

The Zooplankton forms the bulk of the plankton organisms in the Chilka Lake. The occurrence of zooplankton in the five centres for the years, 1950 and 1951, is shown in Table 4.[x] Their seasonal distribution has been arranged according to their order of abundance each year. Comparing the five stations, plankton is most abundant at Satpara in both the years. We shall presently consider in detail the most predominant forms of zooplankton.

Copepods.

The following species constitute the bulk of the Copepod population:

Acartia chilkaensis Sewell, A. centura Giesbrecht, Acartiella major Sewell, A. minor Sewell, Paracalanus crassirostris Dahl, Pseudodiaptomus annandalei Sewell, P. binghami Sewell, P. hickmani Sewell, Oithona nana Giesbrecht, O. brevicornis Giesbrecht, Labidocera pavo Giesbrecht and paratergastes sphaericus (Claus) var. similis Sewell.

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x Available on request at the IPFC Secretariat.

Copepods form 42.58% of the total zooplankton in 1951 and 69.69% in 1951. They, being the most predominant plankton organisms, have been studied on a comparative basis from place to place, month to month and year to year.

Balugaon:

Balugaon is marked by four months of abundance i.e., March, June, September and December in 1950 and again in 1951 by four months viz., March, May, September and December. In 1950, 19% of the total occurrence of Copepods is recorded at Balugaon and 20% in 1951. However, the total quantity is greater in 1950 than in 1951. The peak is in September in the former year whereas it is in May in the latter.

Kaluparaghat:

April, July and September are the abundant months in 1950 and in 1951, February and June. Fourteen per cent of the total Copepods occur in 1950 and 13% in 1951 which are the lowest percentages for all the places combined together for both years. Quantitatively they occur more in 1950 than in 1951. The peak in the former year is in September and in the latter in February.

Rambha:

In 1950, the months of abundance are May, July and November whereas in 1951, March, September and November may be taken as abundant months. In 1950, 27% of the total Copepods occur, which is the highest recorded for the year and in 1951, 13% occur which is one of the lowest for the year. The peaks are in May in the former year and in March in the latter.

Satpara:

April, July, September and December are the abundant months and in 1951, January, March, July and October. Quantitatively 17% of the total Copepods occur in 1950 and 37% in 1951, which is the highest recorded for the year. September is the peak month for the former year and March for the latter.

Arkhakuda:

June, August and December are the abundant months in 1950 and in 1951, January, June, September and December may be regarded as the months of abundance. Percentage of total Copepod occurrence is 23 in 1950 and 17 in 1951. The peaks are in December in both the years.

Copepod population in relation to salinity:

Comparison of Copepod abundance with salinity in each of the five centres shows that the Copepod abundance occurs mostly on either side of the peak of salinity, though there are exceptions in Balugaon and Arkhakuda in the year 1950. Broadly speaking, each year can be divided into two seasons of abundance i.e., pre-peak months and post-peak months of salinity. Sewell (1924) also mentions two seasons but states that probably the times of these vary somewhat from year to year; but he affirms that there seems to be no doubt that the two seasons are correlated with a rise and fall respectively in the salinity of the lake. Esterly (1928) states that in most general terms the Copepods as a group are more abundant at La Jolla in December-April, during which months the salinity is lower than in the other

months. However, it is risky to draw any decisive conclusions from data collected over only a two-year period, as it is evident that there is much variation from year to year in each centre.

Gastropods.

Gastropods occur in the plankton mostly in the veliger stage and sometimes in a slightly more advanced stage. The following species occur in great numerical preponderance in the whole area of the lake:

Tornatina estriata Preston, Nassa denegabilis Preston, N. orissaensis Preston, N. labecula A. Ads., Stenothyra sp., Potamides fluviatilis Pot. & Mach., Litiopa copiosa Preston, and Pyrgulina humilis (Preston).

They are some of the most predominating plankters in 1950, constituting 31.96% of the total zooplankton and 4.73% in 1951. Their occurrence is most abundant at Satpara in both the years. They seem to occur mostly in the summer months and are either rare or absent in the other months. Quantitatively there were less in 1951 than in 1950. Taking the lake as a whole, the peak is in July, 1950, and in June, 1951.

Nauplius larvae.

Nauplius larvae are evenly distributed throughout the lake. But they are most abundant at Rambha in 1950 and at Kaluparaghat and Satpara in 1951. They vary from 16.02% of the total zooplankton in 1950 and 17.69% in 1951. Their occurrence is most abundant in May and June of 1950 and 1951, respectively, if the lake is taken as a whole. Quantitatively, however, they are less abundant in 1951 than in 1950.

Lamellibranchs.

Lamellibranchs are mostly met with in larval stages and they constitute 4.98% of the zooplankton in 1950 and 0.96% in 1951. They occur in abundance at Satpara in the year 1950 but the occurrences are quite insignificant in 1951. They are distributed throughout the year. They seem to occur from March to November 1950, having their peak in July, whereas in 1951 they occur intermittently in February, May, August, September and December having the peak in May.

The following are the predominant species in the Lake:

Modiola undulata (Dunkar), Clementia annandale Preston, Solen ? Konesi Dunker, Theora opalina (Hinds) Meretrix casta Chemn., M. ovum Hanley, Tapes pinguis Chemn., and T. ceylonensis Sowerley.

Other zooplankton organisms.

The following organisms occur at the rate of 0.02 to 0.99% of the total zooplankton in 1950 and 0.01 to 2.19% in 1951.

Protozoa:

Difflugia sp. and polystomella sp.

Cumacea:

Iphinoe sanguinea Kemp and Paradiastylis culicoides Kemp.

Amphipoda:

Periculodes longimanus (Bate & Westw), Paracallipe fluviatilis (G.M. Thomson) and Ampelisca pusilla Sars.

Polychaeta:

Nereis (Nereis) chilkaensis Chilton, N. (Nereis) glandicincta Chilton and Perinereis marjorii Chilton.

Rotifera:

One unidentified species.

Chaetognatha:

Sagitta sp.

Cladocera:

Evadne sp.

Tunicata:

Larvae of one unidentified species.

Isopoda:

[x]Ligia exotica Roux, Apanthura sandalensis Stebling and Calathura borradailei Stebbing.

Decapoda:

Zoea larvae and Lucifer hanseni Nobili.

Mysidacea:

Rhopalophthalamus egregius Hansen and Macropsis orientalis Tattersall.

Fish eggs:

Petroscirtes bhattacharyae Choudhuri and unidentified clupeid eggs.

Fish larvae:

Gobius ostreicola Choudhuri, Petroscirtes bhattacharyae Choudhuri and Hemiramphus limbatus Cuv. & Val.

Combining all the data for the five stations so as to represent the trend for the lake as a whole, 1950 shows the peak in July, the largest composition of which is Gastropods. May and September can also be taken as months of abundance and their chief composition is Copepods and Nauplii. In 1951 the peak of zooplankton occurrence is in March and it is quite abundant also in the months of June and December. The peak as well as the months of abundance show the predominance of Copepods and Nauplii.

It is clearly evident that the number of zooplankton

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[x]Though a semi-terrestrial Isopod, it is found occasionally in the plankton catches.

organisms in the lake was less in 1951 than in 1950 and since our analysis is based on data collected over only two years, it may be premature to draw any conclusion regarding the effect of salinity on the fluctuation of zooplankton in the lake. However, it may be stated that the quantity of zooplankton in the lake is not at all sufficient for the healthy growth of the fish. The gradual depletion of zooplankton may be one of the reasons for similar depletion of fish population in the lake, as is demonstrated by statistical data of fish catches collected by us. The total fish catch (excluding prawns) in the lake in 1948 was 67,147 maunds; in 1949, 59,358 maunds; in 1950, 55,500 maunds; and in 1951, 51,241 maunds.

Phytoplankton.

Table 5[x] shows the occurrence of phytoplankton for the years 1950 and 1951 in the order of their abundance. Unlike zooplankton, the occurrence of phytoplankton was mainly restricted to Satpara and Arkhakuda in both years, though Balugaon too seemed to be nearing the level of Satpara in 1951. Most of the diatoms were of marine origin.

The following are the phytoplankton organisms recorded during the study:

Chlorophyceae:

Spirogyra sp. and Cladophora sp.

Bacillariophyceae:

Stephanopyxis turris (Grev. & Arn.) Ralfs, Coscinodiscus centralis Ehrenberg var. pacifica Gran & Angst, Rhizosolenia bergonii H. Peragallo, R. delicatula Cleve, R. stolterfothii H. peragallo, R. robusta Norman, R. imbricata Brightwell, R. styliformis Brightwell, R. setigera Brightwell, R. calcar avis M. Schultze, R. alata Brightwell, Bacteriastrum hyalinum Lauder, Chaetoceros cibenii Grunow, C. peruvianus Brightwell, C. lorenzianus Grunow, C. compressus Lauder, C. affinis Lauder, C. laevis Leudugar-Fortmorel, C. curvisetus Cleve, C. subtilis Cleve, Ditylum sol Grunow, Biddulphia mobiliensis Bailey, B. sinensis Greville, Thalassionema nitzschioides Grunow, Thalassiothrix longissima Cleve & Grunow, T. frauenfeldii Grunow, Asterionella japonica Cleve, Cocconeis sp., Nitzschia longissima (Brebisson) Ralfs, N. pungens var. atlantica Cleve and Bacillaria sp.

Dinophyceae:

Dinophysis homunculus Stein, D. miles Cleve, Peridinium sp., Ceratium furca sub-species engramma ? (Ehrenberg), C. furca (Ehrenberg), C. trichoceras ? Kofoid, and C. breve (Ostf. & Schmidt).

Rhodophyceae:

Polysiphonia sp.

Myxophyceae:

Lyngbya sp., Anabaena sp. and Oscillatoria sp.

Asterionella japonica: This diatom constitutes the bulk of the phytoplankton in both the years, contributing 49.92% in 1950 and 41.41% in 1951 to the total percentage of phytoplankton. It occurs exclusively at Satpara and Arkhakuda and since its occurrence is

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[x]Available on request at IPFC Secretariat

between March and June it may be deduced that this form needs water of more salinity than the other phytoplankton.

Chaetoceros: Forms 18.94% and 12.10% in 1950 and 1951 respectively of the total phytoplankton and, as in the case of Asterionella, it occurs mainly at Arkhakuda and Satpara but has also been found at Balugaon in lesser quantities and though its main occurrence is between March and July it is also found occasionally in the other months.

Ananaena: Is second in abundance in 1951, having 13.62% of the total phytoplankton, but is entirely absent in 1950. It occurs in abundance at Balugaon but is absent entirely at Satpara and Arkhakuda. Perhaps it does not withstand the intense salinity of those areas or the radical changes in salinity. This is a freshwater alga not capable of withstanding high salinity.

Spirogyra: Comes third in abundance in 1950, constituting 6.32% of the total phytoplankton but in 1951 it falls into insignificance, showing only 1.63%. Being a freshwater algae, it is distributed mainly in the rainy and winter months almost throughout the lake, though its occurrence is more evident in Balugaon and Kaluparaghat areas than in the other parts of the lake.

Coscinodiscus: Is fourth in abundance in 1951, having 4.87% of the total phytoplankton, but in 1951 it shows only 0.52%. It occurs chiefly at Satpara and Arkhakuda.

Rhizosolenia: Is fourth in abundance in 1951, having 10.1% of the total phytoplankton, but in 1950 it shows only 1.15%. It does not occur anywhere in the lake except at Satpara and Arkhakuda.

Thus, except for A. japonica, no other organism maintains the same uniformity of abundance in both 1950 and 1951.

As regards the total monthly occurrence of phytoplankton, June forms the peak month for both the years. It may also be stated that March in 1950 and December in 1951 are months of abundance. Menon (1931) states "lack of sunlight, which is an important factor as far as plant life is concerned, combined with low temperatures, does not allow the diatoms to reproduce freely". As far as Chilka Lake is concerned, it is not clear whether salinity and temperature help the production of phytoplankton, but abundant sunlight does seem to have a definite influence on it, since the total incidence of phytoplankton in the first halves of both years is far more than in the second halves.

Contrary to zooplankton, the total number of phytoplankton organisms occurring in 1951 is more than in 1950. Whether paucity of phytoplankton is always accompanied by abundance of zooplankton and vice versa in each year cannot yet be stated affirmatively until the plankton study undertaken is continued for a few more years.

SUMMARY.

1. The average monthly salinity of the lake Chilka (India) was lower in 1951 than in 1950.

2. Kaluparaghat and Balugaon show similar trends of salinity; Satpara and Arkhakuda show close relationship in salinity fluctuations; and Rambha stands unique in the field of salinity.

3. The zooplankton forms the bulk of the plankton organisms and the peaks occur in July, 1950, and in March, 1951.

4. Copepods form 42 to 70% of the total zooplankton and it has been found that there are two seasons of abundance each year falling on either side of the peak month of salinity.

5. Phytoplankton is more abundant in the earlier half of the year than in the later half due to the availability of sunlight.

6. Phytoplankton occurence is mainly restricted to the Satpara and Arkhakuda areas; most of the diatoms are of marine origin.

7. Asterionella japonica constitutes the bulk of the phytoplankton, contributing 41 to 50% to the total percentage of phytoplankton.

8. Quantitatively zooplankton is more in 1950 than in 1951 whereas the reverse is true for the phytoplankton.

9. It has been presumed, with certain reservations, that the decline in fish catch is due to the depletion of zooplankton in the lake.

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Table 1 - showing the average salinity (‰) of the Chilika Lake for the years 1950 and 1951.

Places	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						1950						
Balugaon	7.43	8.15	9.78	11.58	13.75	21.06	20.37	7.14	4.01	4.57	5.84	6.78
Kaluparaghat	6.41	8.31	9.54	12.09	14.93	22.97	16.29	1.48	0.82	1.74	5.05	5.52
Rambha	10.04	11.37	13.69	14.51	16.92	17.72	19.99	23.17	14.42	12.61	9.47	9.74
Satpara	5.91	11.31	21.87	32.86	24.93	26.92	22.52	4.72	3.35	2.55	2.05	3.46
Arkhakuda	5.66	26.78	27.46	29.34	33.09	34.90	24.50	11.54	7.68	6.74	5.64	3.69
Average	7.09	13.18	16.47	18.27	20.72	24.71	20.73	9.61	6.06	5.64	5.61	5.84
						1951						
Balugaon	7.05	7.54	7.83	8.44	9.89	10.13	13.75	11.98	9.81	5.21	4.69	8.17
Kaluparaghat	5.90	6.54	9.13	9.66	9.92	12.55	10.81	1.60	1.47	1.51	4.04	7.82
Rambha	9.94	9.95	10.10	10.84	10.93	10.96	14.83	24.03	14.18	12.34	11.58	11.79
Satpara	5.41	7.28	19.92	20.89	22.45	23.24	23.38	23.53	0.96	2.64	3.87	7.17
Arkhakuda	5.41	27.24	28.07	28.71	30.39	31.87	32.05	33.35	14.92	9.54	5.91	4.16
Average	6.74	11.71	15.01	15.71	16.72	17.75	18.96	18.90	8.27	6.25	6.02	7.82

Table 2 - showing the total flood level over the crest level[x] of the Naraj Anicut on River Katjuri.
(in feet)

Years	June	July	August	September	October
1950	1.34 (in 2 days)	106.89 (in 31 days)	231.09 (in 31 days)	95.21 (in 31 days)	2.33 (in 5 days)
1951	-	16.55 (in 21 days)	199.85 (in 31 days)	63.53 (in 27 days)	17.46 (in 18 days)

x Crest level of Naraj Anicut is 74 feet above the mean sea level.

Table 3 - showing the average surface temperature of the Chilka Lake for the years 1950 and 1951. (in centigrade)

Months	1950	1951
January	26.6	26.0
February	28.7	26.7
March	31.5	30.2
April	31.2	30.5
May	32.4	31.7
June	33.0	32.8
July	32.1	32.2
August	32.1	32.0
September	31.3	30.3
October	32.2	31.5
November	28.8	28.9
December	25.0	25.2

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IPFC/C54/SYM 8

THE ROLE OF PLANKTONOLOGY IN FISHERIES DEVELOPMENT

by

Tham Ah Kow

The first problem to be faced in fisheries development is to secure information on the nature of the stocks of fish as well as their quantitative distribution in space and time. One approach to this problem is the time honoured method of trial and error. Through the ages a great deal of information on the nature of the fish stocks in different parts of the world as well as their seasonal fluctuations in abundance has been accumulated. This knowledge has played an important part in indicating to marine ecologists the influences which the basic physical and chemical elements such as sunshine, wind, currents, temperature, salinity, etc. exert on the biotic elements such as plankton and fish life. With this knowledge as a background oceanographers, marine biologists and marine ecologists have been able to plan investigations which have revealed the complex mosaic showing the integration of these physical, chemical and biological elements of the marine ecosystem. The present state of our knowledge is aptly summed up by Allee et aliter (1950) who state that, generally speaking, the changes of seasonal character in the animate portion of the marine community reflect the operation of one or more of the following phenomena :-

(1). Direct action by one or more of the basic physical influences upon organisms.

(2). Direct action of the secondary physical influences upon organisms.

(3). Direct action of the basic physical influences upon the inanimate medium of the community.

(4). Direct action of the secondary physical influences upon the inanimate medium of the community.

In an investigation on the physical, chemical and biological characteristics of Singapore Straits Tham (1953) has found that the physical, chemical and biotic elements of the ecosystem are closely integrated.

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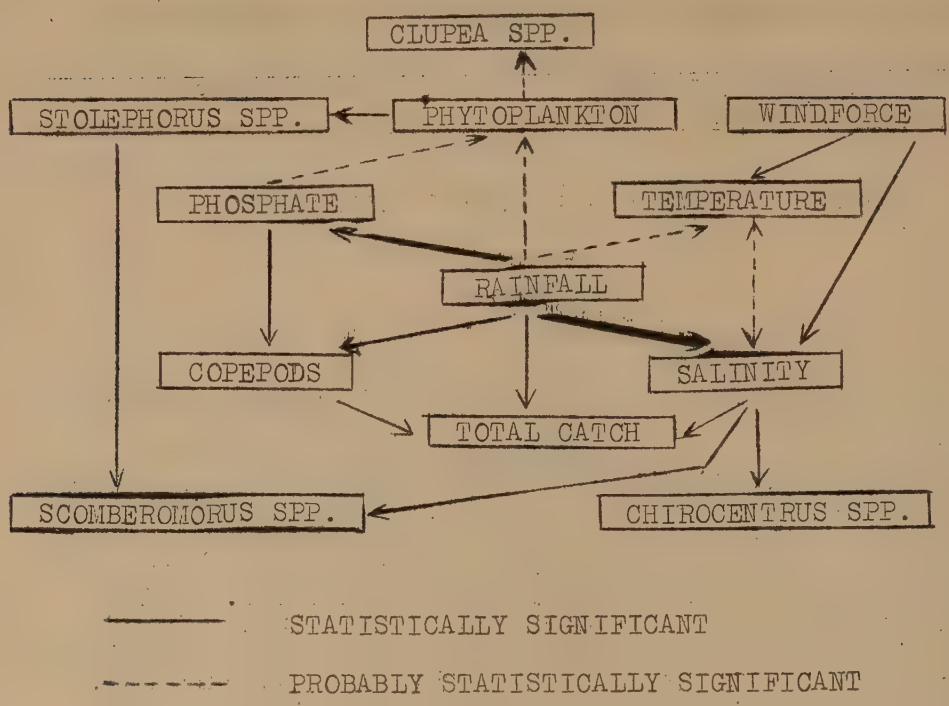
FIG. I.

INTERRELATIONSHIPS



It was found that the physical elements such as rainfall, windforce, temperature, salinity and phosphate are interrelated. Rainfall is correlated with phosphate, salinity, number of copepods and the amount of total catch. Windforce is correlated with temperature and salinity.

2. There are then the inter-relationships between the different biotic elements of the marine ecosystem, viz.:- phytoplankton, zooplankton and fish. In the sea, as in the terrestrial environment, the prime relationship between organisms is that associated with nutrition. A study of the food of different species of fish all over the world has shown that many pelagic fish and the very young stages of almost all species of fish feed on plankton. In a study of the food of the fish of Singapore Straits it has been found that about 80% of the species studied feed on plankton (Tham, 1950). Fishery workers in India have also found that plankton feeding is very widespread among the pelagic fish of the Indo-Pacific region. Bapat and Bal (1950 and 1952) state that almost all the young of the fish species studied by them feed on plankton. According to Chacko (1949) many of the fish of the Gulf of Manaar feed on plankton.

3. Since plankton is such an important item in the diet of fish the quantitative relationship between plankton and fish deserves our attention. It has been observed at widely separated locations all over the world that there is a positive correlationsbetween the density of plankton and the density of the plankton feeding fish population. It has been found that the occurrence of plankton feeding whales is positively correlated with the distribution of the planktonic life upon which they are known to subsist. In Davis Strait it was shown by Hjort and Ruud (1929) that young euphausiid crustaceans (the young are considered to reflect numbers of adult specimens which are not so readily caught with their

vertically hauled nets) had their maximum concentration over certain coastal banks where blue whales also occurred in maximum numbers. Mackintosh (1934) as well as Hardy and Gunther (1935) also found positive correlations between the distribution of blue and fin whales and the abundance of zooplankton, especially their favourite food Euphausia superba. Hardy, Lucas, Henderson and Fraser (1936) investigated the plankton by means of the plankton indicator and, in correlating the numbers of Calanid copepods in the plankton with the amount of herring caught in the same areas, they found that in most instances the greatest number of adult herring were caught in water rich in Calanus. Along the west coast of India Chidambaram and M. Devidas Menon (1945) found that the landings of fish were directly proportional to the quantity of plankton produced in the different months of the year. In Singapore Straits it has been found by Tham (1953) that there is a statistically significant positive correlation between the number of copepods and the amount of fish caught in the same areas. At the same time, the correlation coefficient between phytoplankton and Stolephorus spp. is statistically significant and, in turn, the catch of Stolephorus spp. is correlated with the catch of Scomberomorus spp. In simple terms, where there is an abundance of plankton, an abundance of plankton feeding fish may be expected. In Malayan seas there are large stocks of Stolephorus spp., Clupea (Harengula) spp. and other Clupeids as well as Carangids all of which are voracious plankton feeders. Where these species of fish are abundant, it may be expected that species of Scomberomorus and Chirocentrus will be abundant.

4. One of the foremost problems in fisheries development is to secure an intimate knowledge of the distribution of fish in space and time. The present state of knowledge with respect to the inter-relationships between plankton, plankton feeders and predators such as species of Scomberomorus and Chirocentrus indicates an approach to this problem based on scientific concepts. Since the correlation between the amount of plankton and the fish catch in Singapore Straits is significantly positive, it follows that a study of the distribution of plankton in space and time will serve as a means of indicating the spatial and temporal distribution of the probable centres of aggregration of plankton feeders and their predators. The role of plankton in fisheries development is therefore an extremely important one, as with an intimate knowledge of its distribution in space and time it should be possible to direct fisheries exploitation to the right place at the right time. This approach which is based on scientific concepts is a logical one and should prove more economical and fruitful than the method of trial and error.

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A PRELIMINARY STUDY OF THE HYDROLOGY AND FAUNA OF THE VELLAR ESTUARY (SOUTH ARCOT DT. S. INDIA)

by

K. Ramamurthi*

The Annamalai University is located in the close vicinity of two estuaries - the Coleroon and the Vellar. The suggestion that the Zoology Department of the Annamalai University might avail of the facilities offered by its geographical location, was made in his Presidential address to the Zoology Section of the Indian Science Congress 1942, by Dr. H.S.Rao, who remarked as follows - "The small biological department of the Annamalai University has already some good work in freshwater biology to its credit, and the provision of a small Freshwater Biological Station on the banks of the Vellar or the Coleroon River would encourage useful work on estuarine biology."

It is only very recently that the Zoology Department of the University has found it possible to implement this suggestion by starting a small estuarine biological station at Portonove on the banks of the Vellar estuary, with the aid of grants from the state and Central Governments. The station is being equipped for intensive hydrographical and faunistic studies and also for the investigation of physiological adaptations of estuarine animals of economic importance.

During the last ten months, the station has carried out a preliminary hydrographical survey, chiefly relating to salinity, oxygen and carbonate content. More intensive work including the estimation of phosphates and nitrates and study of currents has been started just now. The fauna of the Vellar estuary, however, has been collected for the past few years and a quantitative study of the plankton, both phytoplankton and Zooplankton is now in progress. The present note records the results of hydrological survey made during the period October, 1952, to July, 1953.

The Vellar River has its source in the Servaroyan Hill in Salem District, and after flowing through the South Arcot District for a distance of over 120 miles opens into the Bay of Bengal at Portonovo, about five miles east of the South Indian Railway line. The Vellar estuary is connected by backwater and lagoons with the Coleroon estuary, which is bigger and situated about 12 miles to the South. The mouth of the Vellar is always open and there is no complete closure of the bar. The shape of the estuary has been changing during the past fifteen years. Till about ten years ago, the sea was rushing in straight into the estuary, but subsequently the tidal wave has shown a tendency to travel across the mouth. This has resulted to a certain extent in drifting the sand across the mouth, but the flushing tendency of the tide has been relatively stronger so that the bar is always open.

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For purposes of investigation, eleven stations in the first instance were selected rather on an arbitrary basis. Periodical "cruises", with the help of a motor boat, up the river for a distance of about 12 miles have been planned for collecting data relating to depth, composition of water, nature of sediment and velocity of currents, distribution of plankton etc.

But on the basis of the hydrological data, chiefly the chlorinity conflict, the estuary can be demarcated into (1) the marine zone (2) the gradient zone (3) the tidal zone and (4) the fresh water zone. In addition to this, may be mentioned (5) the salt water pools or lagoons and (6) the backwater which may be regarded as subdivisions of the marine and gradient zones but with rather different faunal conditions.

METHODS:

Salinity: - Weekly salinity records have been maintained for eight stations during the last ten months. Hourly salinity records were made for two days on 17-1-53 and 18-1-53 at station 2 in the gradient zone (Please vide Tables I, II, III, IV and graphs I, II, III and IV)*

Recordings for salinity of water near the bank were taken for all the zones (eight stations - vide map) both at high tide and low tide. But with respect to station No. 1 belonging to the gradient zone not only surface salinity but also the salinity of water in the middle of the river from the bottom and also from a depth of 3 feet from the surface. Temperature also was recorded at the time of sampling. Water samples were collected by water sampling bottles. The determination of salinity was made by Harvey's method (4) and frequently checked up with titration against standard sea water. Salinity calculations from Knudsen's Tables after chlorinity estimation were also carried out to check the results obtained by Harvey's method.

The marine zone includes stations 5 and 6. The mean salinity here at high tide is high, being about 30.38 o/oo (Vide Table II.A) and the bottom salinity and the surface salinity, judging from the observations made so far, are equal. (Vide Table I.A). The fauna is distinctly marine. Among the interesting forms that have been collected from this zone may be mentioned, Trygon (sting ray), Rhynchobatis, cake urchins, heart urchins brittle star, Umbonium, Aplysia, Pleurophillidea, Notarchus, Pleurobranchia, Cavernularia, Haminea, Synapta, Thalassema and rarely Lingula. Many of these forms are available during August and September and again during January and February. The marine element in the plankton predominates.

No. 8 station is peculiar in being cut off completely from the estuary except during the North East Monsoon when it is connected with the marine zone. The salinity is subject to wide fluctuations, rising to 80 o/oo during the hot season. During January and February when the salinity varies from 26.32 o/oo to 34.22 o/oo. Mullet fingerlings, Therepon Hydroid colonies and Polyzoa thrive in this zone.

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* All tables and graphs and the map are available at the Secretariat.

THE GRADIENT ZONE:-

This includes stations 1, 2, 3, 4 and the backwater. Station No. 7 is a shallow water collection which is fairly extensive and connected with the estuary. The mean salinity at high tide is 26.47 o/co and there is not much fluctuation in salinity at high tide and low tide. As the pool is slushy and very shallow - there is no salinity gradient at this place.

Station No. 7 is connected with the commencement of the gradient zone and is characterised by abundance of Uca and Telescopium telescopium throughout the year and Oncidium in some seasons.

The gradient zone proper shows a vertical gradient of salinity. The salinity range of surface water is larger than that of the bottom which always shows a higher salinity than the surface. The maximum difference being 19.68 o/oo.

In this zone we see a transition in the faunal community. Potamides cingulatus is very common being most abundant about station No. 4. In the lower reaches of this zone, Sanguinolaria, Sipunculids, Solen, Standella, and other burrowing bivalves are common. Cerebratulus, Sipunculids, Edwardsiella (?) Gobioides, Polychaets, are also common. Oncidium, Periopthalmus, and Uca are also met with in this zone. So also Littorina appears higher up in this region. At the upper limit of this zone Neritina Assiminea are met with. Septaria dravidica was originally collected from this zone. Oysters are occasionally met with, but are abundant in the backwater, some four miles to the south of the commencement of the zone.

TIDAL ZONE:-

In this zone the salinity gradient is not so marked but tidal flow is noticed. Septaria is found. At the upper limits of this zone occurs Melania crenulata the only fluviatile gastropod known to have a free larva stage.

Beyond this zone some 14 miles from the mouth comes the freshwater zone, with Corbicula, Parreysia and other characteristic freshwater fauna.

SALINITY.

The Vellar estuary is lower estuarine, according to Klugh's classification of estuaries on the basis of salinity greater or less than 15 o/oo as the salinity is generally above this value. The salinity of the surface water at high tide (excluding that of brackish water pools) ranges from 0.60 o/oo during floods, to 36.77 o/oo. During floods (Vide Table IV) the estuary contains practically freshwater, the surface salinity being 0.80 o/oo. The mean salinity during the period of survey ranges from 21.36 o/oo to 30.38 o/oo at high tide, and from 16.38 o/oo to 26.20o/oo at low tide. The surface salinity decreases upstream, the range of fluctuation in the month of August being from 34.03 o/oo at the mouth to 15.0 o/oo at the tidal zone. The diurnal variation recorded on 17.1.53 and 18.1.53 shows a range from 5.4 o/oo to 27.95 o/oo at station No. 2 in the gradient zone (Vide Table VI).

The interesting feature of the salinity in the estuary is its vertical gradient of salinity. From the data collected so far

the mean surface bottom difference at Station No. 2 is 8.73 o/oo at low tide and 3.80 o/oo at high tide. The difference may be as much as 15 o/oo at certain times.

In a survey made on 23-8-53 the following data were collected:

Zones	Mean difference between surface & bottom salinities o/oo	Remarks
I. Marine Zone	0.40	At some points no difference.
II. Gradient Zone	13.04	The difference progressively increases upstram 4.72 at the commencement of the zone to 19.68.
III. Tidal Zone	8.78	The difference progressively decreases upstream from 14.7 at the commencement of the zone to 2.6

In the marine zone, at the mouth there is little or no surface bottom difference in salinity, but upstream it becomes very characteristic and again diminishes in the upper limits of the tidal zone.

The systematic collection of data relating to the percentage difference between surface and bottom water salinities is being continued, with a view to the precise definition of the magnitude and extent of the tidal wedge and its variation in the different seasons.

The greatest seasonal fluctuation in salinity is noticed in the salt pool (Station No. 8) which has a mean salinity of 38.17 o/oo at low tide and 38.88 o/oo during the North East Monsoon when it is connected with the marine zone, and 80.28 o/oo during the hot months. No organisms other than Chironomus larvae are found at this station during the period of high salinity. In November and December, when the salinity falls, Hydrozoa, cake urchins, mullet fingerlings, Therapon etc colonise this zone.

The effect of rainfall is very patent in the month of December. In December, 1952, there were heavy rains and floods and salinity, as stated above, fell to 0.60 o/oo. (Vide Tables III, IV & VI). During this period the fauna is freshwater at the surface. Rana and other freshwater animals are common even at Station No. 5 in the marine zone. On two days hourly records of salinity were maintained and the results are interesting. At 7 P.M. the tide was rising and the salinity was 17.03 o/oo. The salinity continued to increase till 12 midnight, when it was 27.11 o/oo and at 1.A.M. it was 21.42 o/oo. Then there was a sudden drop to 5.80 o/oo at 2.P.M. The fall in salinity continued till about 8 next morning. (Vide Table VI, VI.A & Graph V) Station No. 7 in the gradient zone as in the case of Station No. 8 in the marine zone, salinity varies considerably, the highest record being 49.80 o/oo and lowest 1.60 o/oo.

A few anomalies were noticed in the incidence of low and high salinities at low and high tides respectively. This is being critically investigated with a view to determining whether it is due to imperfect observations of the exact state of tides, or due to strong winds and water movements or due to strong winds and water movement and much restricted ebb and flow in the river. The currents in the estuary and the influence of tributaries are factors which affect the estuary. This aspect also is being investigated. The contamination of the river from village drains does not occur except at the upper limit of the tidal zone.

THE PLANKTON:-

The incidence of the marine element in the plankton has been alluded to already. Depending on the tide and currents, marine plankton extends at times into the gradient zone. Ctenophores, Salps, ascidian tadpole Tornaria, Pilidium etc occur at times in the plankton.

DISSOVED OXYGEN:-

For determination of dissolved oxygen content, samples were taken from station No. 7 and 8 and I (shore). Readings for temperature were taken. Oxygen content was determined by Winkler's method. The maximum that was recorded at station No. 8 was 5.95 cc/lit and minimum was 0.3490 cc/litr. The noteworthy feature in this station was the sudden decrease in oxygen content from April onwards. The maximum record for Station No. 7 was 5.17 cc/litr and minimum was 2.37 cc/litr. With regard to Station No. 1 the maximum recorded was 7.2 cc/litr and minimum was 0.56 cc/litr. The greatest fluctuation in dissolved oxygen content is noted in the case of Stations Nos 1 & 8 (Vide Graph VI and Tables VII, VIII & IX).

HYDROGEN ION CONCENTRATION:-

There was no significant seasonal variation in the pH. At Station No. 8 the pH range was 8.5 - 8.8 and at Station No. 1 it was 8.4 throughout (Vide Tables VII & IX).

CARBONATES AND BICARBONATES:-

For determination of carbonates and bicarbonates samples were collected from Station Nos. 8, 7 and 1. The usual method was followed by titrating the sample of 100 cc with N/20 Hcl using Methyl Orange and Phenolphthalin as indicators. From the data collected, the maximum that was recorded at Station No.8 for carbonates was 8.1 mg/100 cc and minimum was 3.3 mg/100 cc. The maximum ~~that~~ was recorded at Station No. 8 for bicarbonates was 23.00 mg/100 cc and minimum was 5.4 mg/100 cc; with regard to Station No. 1 for bicarbonates the maximum was 28.07 and minimum was 8.24. The fluctuation in the carbonate and bicarbonate content is very marked at Station No. 8 (Vide Tables VII, VIII and IX and Graph VII and VIII).

FISHERIES:-

Scope and possibilities:-

Meretrix meretrix, Catylysia are collected from the estuary for manufacture of lime. The oysters in the backwaters are eaten by some of the poor classes, but of late, most of the oyster beds have been indiscriminately destroyed for the shells

which are used in lime manufacture. It is time that some restriction is imposed on this destruction of oysters in the area, which are of good quality and found in a zone free from sources of contamination of water.

Prawn fishing is done on a small scale in the backwater and also in the estuary. Soletellina diphos which is eaten by fishermen, is collected during most months of the year and in all the zones. But the most common fish, the mullets, which are available throughout the year, are collected by throw net from a canoe at the rate of about 30 mullets per catch. Sometimes a team of six or more canoes carry out this operation.

The land adjoining the estuary is very well-suited for developing mullet farms. The Biological Station of the University is located in the "gradient zone" of the estuary and is surrounded by extensive low land of 120 acres through which tidal water flows by two narrow channels of about 2½ feet in width. The land is low enough to facilitate flow of tidal water through feeding channels, but without risk of inundations during monsoon months. Mullet fingerlings often migrate into brackish water pools in the locality. The construction of ponds and sluices to regulate the flow of water will incur little expenditure. Mullets are available as far as the fresh water zone, and in the backwaters, usually mature mullets are available. Mature mullets are available in the estuary during the months of October, November, December and January and the fingerlings in November, December and January. In the salt pools mullets are common during November and December. Judging from the abundance of mullets in the estuary and the size to which they grow, there is great scope for developing a successful mullet farm at Portonovo.

SUMMARY

A Preliminary Hydrographical Survey of the Vellar Estuary conducted during the past ten months shows a marked zonation both in salinity and faunal communities. Three zones may be recognised:-

(1) A Marine Zone, in which there is practically no difference in bottom-surface salinities. This zone is characterised by a predominantly marine faunal community.

(2) The Gradient Zone. In this there is a vertical gradient of salinity and the difference in bottom-surface water salinities progressively increases from the commencement of the zone to the upper limit of the zone. This zone is characterised by typical estuarine fauna.

(3) The Tidal Zone. Here, the difference in surface-bottom water salinities progressively decreases till it merges into the freshwater zone.

In the extensive flats adjoining the estuary, there is good scope for developing a mullet farm. A thorough hydrographical and faunistic survey of the estuary has been planned and is in progress.

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LIST OF TABLES

TABLE I
Mean monthly shore Salinity % readings from Oct., 1952, to July 15th, 1953, at Low and High Tides.

TABLE I-A
Readings taken during I survey dated 23-8-53.

TABLE II (A)
Mean Salinity % readings during the period of survey at different Stations.
(B) Maximum and Minimum Salinity % readings for each Station.

TABLE III
Shore Salinity % readings taken on 3-12-52 (3 days after cyclone and heavy rains) at Low and High Tides.

TABLE IV
Salinity % readings taken on 10-12-52 (after floods) at Low and High Tides.

TABLE V
Total monthly rainfall from Oct., 1952, to July, 1953, at Porto Novo.

TABLE VI
Hourly Salinity % readings on 17-1-53 and 18-1-53 at Station No. 2.

TABLE VI (A)
Readings to show the water level at an interval of one hour.

TABLE VII
Readings for Oxygen content, Carbonates, Bicarbonates, Temperature and pH at Station No. 8 from January to July, 1953.

TABLE VIII
Readings for Oxygen content, Carbonates, Bicarbonates, Temperature and pH at Station Nos. 1 & 7 from January to July, 1953.

TABLE IX
Mean monthly readings for Oxygen content, Carbonates, Bicarbonates, Temperature and pH from January to July, 1953, at Station Nos. 1, 7 & 8.

TABLE X
Map of the Vellar Estuary

LIST OF GRAPHS

I. Graph showing the mean monthly shore salinity % from October, 1952, to July, 1953, at station Nos. 2 and 3 at low and high tide.

II Graph showing the mean monthly shore salinity % from October, 1952, to July 15, 1953, at station Nos. 4, 5, and 6 at low and high tides.

III Graph showing the mean monthly salinity % from October, 1952, to 15th July, 1953, at station No. 1 (II) surface, bottom, 3' depth and surface bottom difference at low and high tides.

IV Graph showing the mean monthly shore salinity % from October, 1952, to 15th July, 1953, at station No. 1, and from October, 1952, to February, 1953, at station No. 7, and from October, 1952, to May, 1953, at station No. 8 both low and high tides.

V Graph showing hourly shore salinity % on 17-1-53 and 18-1-53.

VI Graph showing the mean monthly oxygen content at station Nos. 1, 7 and 8.

VII Graph showing the mean monthly Carbonate readings at station Nos. 1, 7 and 8.

VIII Graph showing mean monthly Bicarbonate readings at station Nos. 1, 7 and 8.

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VARIATIONS IN ZOOPLANKTON ABUNDANCE IN THE CENTRAL EQUATORIAL PACIFIC, 1950-1952

by

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The abundance of zooplankton as an index to potential fish production is significant to the study of the high seas fishery resources of the tropical and subtropical regions of the central Pacific being carried out by the Pacific Oceanic Fishery Investigations (POFI) of the U. S. Fish and Wildlife Service. In this report we shall review the primary results of our zooplankton sampling in the equatorial Pacific from our initial year, 1950, through 1952. The data will be examined for variations associated with latitude, longitude, and season. We shall point out, very briefly, certain relationships which appear to exist among the hydrographic features of the environment, the zooplankton, and the tunas.

Zooplankton is a basic food of much of the vertebrate fauna of the sea. It is directly utilized even by such large and fast moving fish as the tunas, the group of fish presently under study by these Investigations. For example, representatives of the following groups have been captured in our plankton nets and have also been found among the stomach contents of maturing and adult yellowfin tuna (Reintjes and King 1953).

mysids	shrimps	pteropods
euphausiids	palinurid larvae	cephalopods
amphipods	brachyuran larvae	tunicates
stomatopod larvae	heteropods	fish larvae and juveniles

The bulk of the zooplankton, however, reaches the tunas indirectly through intermediary forage organisms such as squid, fish, and the larger shrimp.

Earlier plankton sampling in this area has consisted principally of scattered collections. Some of the major oceanographic expeditions, the Challenger, the Albatross, and the Dana, while traversing the central Pacific, made a few hauls which were largely qualitative and chiefly of value in systematic and distributional studies. The Carnegie visited the central Pacific in 1929 and made quantitative hauls on a generally north-south section crossing the Equator. The resulting data (Graham 1941) are difficult to compare with our own but do provide evidence on variation in plankton dry weights as related to latitude and the equatorial current system. The work being carried out by POFI is, however, the first comprehensive quantitative survey of zooplankton abundance in the equatorial central Pacific and the first attempt to correlate the physical and chemical environment, zooplankton abundance, and tuna catch.

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The Pacific Oceanic Fishery Investigations is under the directorship of Mr. O. E. Sette, who has contributed many of the ideas expressed in this report. Miss Joan Demond1/ and Mr. Thomas S. Hida2/ assisted in making the zooplankton volume determinations on which this report is based. We are indebted to Messrs. Garth I. Murphy3/ and Richard S. Shomura3/ for supplying the yellowfin tuna catch records. The hydrographic data were collected and processed under the supervision of Messrs. Thomas S. Austin4/ and Townsend Cromwell5/. The author is responsible for combining and averaging the fish catch records and the inorganic phosphate data for the purpose of comparing them with the zooplankton volumes.

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This report is based on 405 collections taken on 10 cruises of the Fish and Wildlife Service vessel Hugh M. Smith during the years 1950 to 1952. The time of year of each cruise, the general area visited, and the number of collections taken are listed in table 1. The area sampled (fig. 1) extends from 120° W. longitude on the east to 180° W. longitude on the west, with a range of latitude from 27° N. (on 175° W. longitude) to 14-1/2° S. (on 172° W. longitude). The geographic position for each plankton station and the value of each collection as a count or volume of zooplankton have appeared, or will appear, in other publications of the Fish and Wildlife Service (King and Demond 1953; King and Hida MS). Most of the cruises consisted of one or more long series of stations (as illustrated in fig. 2 for cruise 5) extending in a north-south direction, crossing the Equator and the major equatorial currents.

Cruises 2, 5, 8, 15, and 16 were combined hydrographic and plankton cruises and thus provide information on currents, temperatures, oxygen, and inorganic phosphate for comparison with the zooplankton abundance. Cruises 7, 9, and 18 of the Smith were primarily tuna fishing expeditions on which some plankton collections were made; cruises 11 and 14 were combination fishing, hydrographic, and plankton cruises.

The plankton nets used in making these collections were 1 meter in mouth diameter and about 5 meters in overall length. Front and middle sections of the net were of 30xxx silk grit gauze (apertures 0.65 mm. square); the rear section and bag were of 56xxx grit gauze (apertures 0.31 mm. square). The 30xxx grit gauze comprised about 97 percent of the straining surface of the net.

Nets of this mesh size retained the tuna eggs (of about 0.80 mm. diameter) and tuna larvae, the capture of which was one object of the study. Almost all phytoplankton passed through the net, and thus a relatively "clean" sample of zooplankton was obtained. A flow meter suspended in the mouth of the net gave an estimate of the amount of water strained on each haul. Thus the results could be expressed in terms of cubic centimeters of zooplankton per unit of water strained.

As we were limited to a single tow at each station, we chose to use, for the greater part, an oblique haul. This method of hauling has been shown by

Winsor and Clarke (1940) to be subject to less sampling error and to provide more reliable and consistent results than vertical or horizontal hauls. In making the haul the net was lowered at a slow uniform speed to a calculated depth of 200 meters (estimated from wire out and angle of stray from the vertical, assuming the towing wire to describe a straight line in the water), and then retrieved at the same slow uniform speed. Following this practice the oblique tow to 200 meters required about 30 minutes, and approximately equal amounts of time were spent at all depths. The amount of water strained on each haul varied from 1,000 to 1,500 cubic meters.

For cruises 2, 5, 7, and 8 a measured fraction of each sample was counted and the displacement volume was determined (the zooplankton counts are not utilized in this report). For all subsequent cruises the displacement volume of the entire sample was measured but no counts were made. During the course of the work refinements in technique have been introduced which tend to give a more accurate estimate of the amount of zooplankton --as food-- present at each station. Detailed descriptions of the methods employed in processing the samples are given in recent reports (King and Demond 1953; King and Hida MS).

For purposes of comparison the zooplankton volumes were grouped according to their position into 5-degree intervals of latitude and 10-degree intervals of longitude. The intervals of latitude chosen were as follows: 0°00' to 4°59', 5°00' to 9°59', etc. The few samples occurring at 0°00' were assigned to the 0° - 4° N group or the 0° - 4° S group depending upon the direction the section was being traversed, e.g., if the direction of movement was to the south the sample was assigned to the southern (0° - 4° S) group. The intervals of longitude selected were as follows: 120° to include samples from 115°00' to 124°59', 130° to include samples from 125°00' to 134°59', etc.

When the data from all 10 cruises were combined irrespective of longitude and season into 5-degree latitudinal groups and graphically portrayed as in figure 3B, the peak of abundance was found to occur near the Equator in the South Equatorial Current but displaced slightly to the northward and spilling over somewhat into the Countercurrent. The poorest areas within the range of latitude sampled were those in the North Equatorial Current. An average of zooplankton volumes, included in figure 3, obtained on four cruises in Hawaiian waters during the years 1951 to 1953 shows that Hawaii ranked a little higher than parts of the North Equatorial Current, but considerably lower than the equatorial region.

Figure 3C is a composite, however, including many cruises occurring at different times of the year and with sampling along different longitudes, from 120° W. to 180°. A more accurate picture may be obtained from table 2, where the latitudinal variation is shown for each 10 degrees of longitude, Table 3 is included to point out differences among four major cruises, with two cruises (2 and 8) occurring during the northern winter season and two cruises (5 and 11) occurring in the late northern summer. Through an analysis of variance, King and Demond (1953) found no significant differences ($P > 0.05$) between longitudes for both cruises 5 and 8 but highly significant differences ($P < 0.01$) between cruises. In general it appears that the equatorial region produced a larger zooplankton crop in the winter of 1950 than in the winter of 1951. The summer crops of the two years are about equal.

Table 4 was constructed for the purpose of examing further the variations with season of the year and with longitudes. Since the sampled area included portions of both hemispheres and since we as yet had no evidence as to natural seasons in zooplankton abundance in the tropical Pacific, for purposes of this study the calendar year was divided into quarters as indicated in table 4. Since latitude is a third variable to be taken into account, table 4 is arranged to show variations with longitude and "season" for three latitudinal groups: 4° N - 0°, 0° - 4° S, and 9° N - 4° S. These are the latitudes for which we have the most observations and they are also the areas of greatest

plankton production. The border means in the table indicate that longitudes 160° to 120° produced in general the largest volumes, although our data are not sufficiently complete to provide entirely reliable conclusions. Figure 4A, which summarizes the variation with longitude for all observations between 9° 59' N. and 4° 59' S. latitude, shows a gradient of increasing abundance from west to east, with a leveling-off east of 140°. Certain of the longitudes were sampled at only one period of the year, however, so this picture of longitudinal variation may change somewhat with future sampling.

In respect to seasonal variation, the period January--February--March ranked low for most longitudes. July--August--September, almost without exception, marked the period of greatest production (great significance should probably not be attributed to the three observations for October--November--December, 4° N. - 0° latitude, 160° W. longitude). Perhaps the most striking feature of the data as portrayed in figure 4B is the absence of the great seasonal variation which is so characteristic of plankton abundance in higher latitudes.

Tropical seas have been considered less productive than those of higher latitudes on the grounds that surface heating in the tropics results in a stable stratification of the sea, thus limiting vertical mixing by convection which would bring nutrients to the euphotic zone (Delsman 1939, Graham 1941; Sverdrup et al. 1942, p. 942). Such thermal stratification does apparently exist throughout much of the tropical and subtropical Pacific. It was learned, however, from the last cruise of the Carnegie, in 1929, that these generally stable conditions are disrupted at the Equator by a divergence of the surface waters resulting in upwelling. The latter was considered responsible for enrichment of the surface waters and the production of much greater concentrations of plankton than were found in higher latitudes within the tropics and subtropics (Graham 1941).

The existence of the divergence at or near the Equator, with resultant upwelling of nutrient-rich water, is substantiated by the researches of this laboratory. The nature of the upwelling and the causal forces involved are discussed by Cromwell (1951 and MS) and Sette (MS). Apparently the strong east and southeast trade winds which prevail for the greater part of the year and the effect of the Coriolis force are the major influences governing this equatorial current system.

Basic nutrients, brought to the surface by the equatorial upwelling, are essential to the growth of phytoplankton; in the present studies dissolved inorganic phosphates are used as an indicator of these nutrients. Figure 3A shows the variation in organic phosphate with latitude, as found on seven cruises in the central Pacific. We have no empirical explanation at the present time for the asymmetric distribution of phosphate with respect to the Equator. This may be related, however, to differences in the meridional components of the surface current in the region of the Equator, or perhaps to differences in the rate of utilization by phytoplankton. As indicative of the phosphate $\rightarrow$ phytoplankton $\rightarrow$ zooplankton eutrophic linkage, we have found a highly significant positive correlation between zooplankton and inorganic phosphate on the long north-south sections crossing the Equator (King and Demond 1953).

The frequently appearing "fronts" (Cromwell MS) in the zone of convergence north of the Equator, at 2° to 4° N. latitude, may also contribute to the apparent greater abundance of life in the equatorial region. Floating organisms of high buoyancy may tend to congregate along the fronts just as driftwood does along a "current rip." Motile plankton forms capable of resisting the downward currents would also tend to concentrate in the surface waters; thus a rich pasturage for plankton-feeding animals could result.

The unusual abundance of marine life in the region of the Equator and the Countercurrent has been observed by many expeditions and world travelers while crossing the Pacific. The surface manifestations of the enrichment may have

a counterpart in certain features of the bottom deposits of this area of the Pacific. Revelle (1944) points out the agreement between the southern boundary of the Countercurrent and the northern border of the Pacific Globigerina ooze area. Arrhenius (1950) concluded from an examination of bottom samples collected by the Swedish Deep-Sea Expedition that in the Pacific the "biogenous component" increases strongly in the region between the Equator and the southern boundary of the Countercurrent "-- where a biolith, rich in fossils of foraminifera, radiolaria, and diatoms is thus deposited."

From October 1950 to June 1953 the Pacific Oceanic Fishery Investigations conducted experimental longline fishing for tuna on 10 cruises in waters of the equatorial Pacific. The fishing took place in essentially the same area with about the same boundaries of latitude and longitude as our plankton investigations. The longline method of fishing and the results obtained on these cruises have been reviewed by Murphy and Shomura (1953 and MS).

In the Pacific several species of tuna are taken by the longline fishing method. In the equatorial central Pacific the yellowfin, Neothunnus macropterus (Temminck and Schlegel), constitutes by far the largest percentage of the catch. When the catches, in terms of yellowfin captured per hundred hooks fished at each station, are combined in 5-degree intervals of latitude, irrespective of longitude and time of sampling -- as was done for the zooplankton to produce figure 3B, the result (fig. 3C) indicates the area of best catch to be at 4°N - 0° latitude. The average catch rate drops off very fast to the north and south of these latitudes.

It is rather obvious that there is more than a casual relationship between zooplankton and yellowfin tuna, but, as might be expected when using the average values of zooplankton and fish from a number of disconnected cruises, the latitudinal distribution of zooplankton and fish do not precisely correspond. There are several reasons why this might be so, but for the present discussion it is enough to establish that one of the basic food constituents of tuna -- plankton -- reaches a peak of abundance near the Equator in a region high in mineral nutrients and that this same region is also found to contain maximal concentrations of yellowfin tuna.

In summary it would seem that upwelling at the Equator, resulting from the equatorial divergence, replenishes the supply of nutrients in the surface waters and provides a suitable environment for the growth of phytoplankton. Since animal life depends on its food supply, conditions in this region are favorable for the development of a zooplankton population. Convergence in the surface water layers, occurring usually at 2° to 4° N. latitude, between the Equator and the southern boundary of the Countercurrent, tends to concentrate the zooplankton into a rich pasturage for forage organisms. These in turn serve as food for the larger fishes such as the tunas. Thus, a productive cycle in the sea, starting from upwelled equatorial waters, results in the formation of a vast potential food resource in the form of yellowfin tuna.

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Table 1.--Cruise period, general area visited, and number of zooplankton samples collected on 10 cruises of the U.S. Fish and Wildlife Service vessel Hugh M. Smith during the years 1950 to 1953

Cruise	Cruise period	Approximate longitude	Range of latitude	Number of samples
2	Jan. - Feb. 1950	170°W	23°N-4°S	12
	Feb. - Mar. 1950	160°W	19°N-4°S	12
5	June 1950	180°	27°N	1
	July 1950	170°W	25°N-5°S	26
	July - Aug. 1950	160°W	20°N-4°S	24
7	Oct. - Nov. 1950	160°W	20°N-2°N	23
	Nov. 1950	170°W	6°N	1
8	Jan. 1951	150°W	6°N	1
	Jan. - Feb. 1951	160°W	20°N-7°S	41
	Feb. - May 1951	170°W	20°N-14°S	45
9	June 1951	180°	25°N	1
	June 1951	170°W	22°N-4°S	13
	June 1951	160°W	20°N-1°S	11
11	Sept. 1951	150°W	19°N-4°S	45
	Sept. 1951	160°W	2°N-1°N	5
14	Jan. - Feb. 1952	150°W	7°N-3°S	7
	Jan. - Feb. 1952	160°W	1°N-6°S	9
	Mar. 1952	170°W	6°N-5°S	13
	Mar. 1952	180°	9°N-8°S	18
15	May - June 1952	140°W	9°N-7°S	60
16	Aug. 1952	150°W	2°N-3°S	16
18	Oct. 1952	120°W	7°N-8°S	13
	Nov. 1952	130°W	9°N-4°S	10

Table 2.--Variation in zooplankton abundance as associated with latitude and longitude without regard to time of year of sampling. Figures given are means of zooplankton volumes (as cc./1000m.^{3} of water strained). [Number of samples for each area included in parentheses.]

	180°	170°	160°	150°	140°	130°	120°	Mean
29°-25°N	12.5(2)	27.1(1)	-	-	-	-	-	17.4(3)
24°-20°	-	16.5(6)	24.6(4)	-	-	-	-	19.8(10)
19°-15°	-	21.6(8)	31.7(10)	16.4(3)	-	-	-	25.7(21)
14°-10°	-	14.7(13)	22.0(21)	20.1(8)	-	-	-	19.4(42)
9°-5°	19.6(5)	23.8(19)	30.6(31)	26.8(13)	51.2(18)	37.3(3)	41.8(2)	32.6(91)
4°-0°	27.2(5)	37.0(24)	37.0(34)	37.7(28)	34.8(17)	35.8(4)	38.2(6)	36.5(118)
0°-4°	25.9(4)	32.6(28)	36.8(20)	39.9(15)	38.9(19)	34.2(3)	37.9(3)	35.9(92)
5°-9°	15.4(4)	20.8(8)	28.7(5)	-	21.8(6)	-	29.6(2)	22.5(25)
10°-14°S	-	16.5(3)	-	-	-	-	-	16.5(3)
Mean 1/	24.1(14)	31.7(71)	34.6(85)	35.8(56)	41.7(54)	35.8(10)	38.8(11)	

1/ For latitudes 9°N to 4°S only.

Table 3.--Variation in zooplankton abundance with latitude as obtained on four major cruises of the Hugh M. Smith. Values given are mean zooplankton volumes (as cc./1000m.^{3} of water strained). [Number of samples for each area included in parentheses.]

Latitude	Cruise 2 Feb. 1950		Cruise 5 July 1950		Cruise 8 Feb.-Mar. 1951		Cruise 11 Sept. 1951	
	170°	160°	170°	160°	170°	160°	150° Section 1	150° Section 2
24°-20°N	10.8(2)	-	21.4(2)	28.9(1)	14.5(1)	15.4(1)	-	-
19°-15°	-	17.6(1)	25.9(3)	28.6(2)	14.2(3)	10.5(1)	-	16.4(3)
14°-10°	11.2(3)	6.6(3)	20.4(4)	23.3(6)	12.5(5)	19.7(5)	17.0(3)	22.0(5)
9°-5°	23.1(2)	26.4(3)	25.4(6)	43.2(5)	21.0(6)	23.4(12)	24.4(5)	31.0(4)
4°-0°	53.2(2)	74.0(2)	42.0(4)	62.2(4)	35.4(12)	24.7(15)	41.6(10)	45.0(6)
0°-4°	53.7(3)	57.7(3)	53.8(5)	36.5(6)	21.4(8)	36.8(4)	45.6(5)	58.6(4)
5°-9°	-	-	31.5(1)	-	19.3(7)	34.1(3)	-	-
10°-14°S	-	-	-	-	16.5(3)	-	-	-

Table 4.--Variation in zooplankton abundance with longitude and time of year of sampling for certain latitudinal zones. Values are mean zooplankton volumes (as cc./1000m.^{3} of water strained). [Number of samples for each area and season enclosed in parentheses].

	Jan.-Feb.-Mar.	Apr.-May-June	July-Aug.-Sept.	Oct.-Nov.-Dec.	Mean
4°N-0°					
180°	27.2(5)	-	-	-	27.2
170°	36.8(19)	20.1(1)	42.0(4)	-	37.0
160°	29.2(19)	27.7(3)	46.4(9)	68.0(3)	37.0
150°	25.0(3)	-	39.3(25)	-	37.7
140°	-	34.8(17)	-	-	34.8
130°	-	-	-	35.8(4)	35.8
120°	-	-	-	38.2(6)	38.2
Mean	31.8	33.1	41.2	44.3	
0°-4°S					
180°	25.9(4)	-	-	-	25.9
170°	27.5(17)	29.2(6)	53.8(5)	-	32.6
160°	38.5(12)	27.6(2)	36.5(6)	-	36.8
150°	26.3(1)	-	40.9(14)	-	39.9
140°	-	38.9(19)	-	-	38.9
130°	-	-	-	34.2(3)	34.2
120°	-	-	-	37.9(3)	37.9
Mean	31.2	35.9	42.4	36.1	
9°N-4°S					
180°	24.1(14)	-	-	-	24.1
170°	30.2(46)	27.8(9)	39.3(15)	19.2(1)	31.7
160°	29.9(46)	28.7(7)	42.6(20)	42.8(12)	34.6
150°	25.4(8)	-	37.5(48)	-	35.8
140°	-	41.7(54)	-	-	41.7
130°	-	-	-	35.8(10)	35.8
120°	-	-	-	38.8(11)	38.8
Mean	29.0	38.6	39.1	38.7	

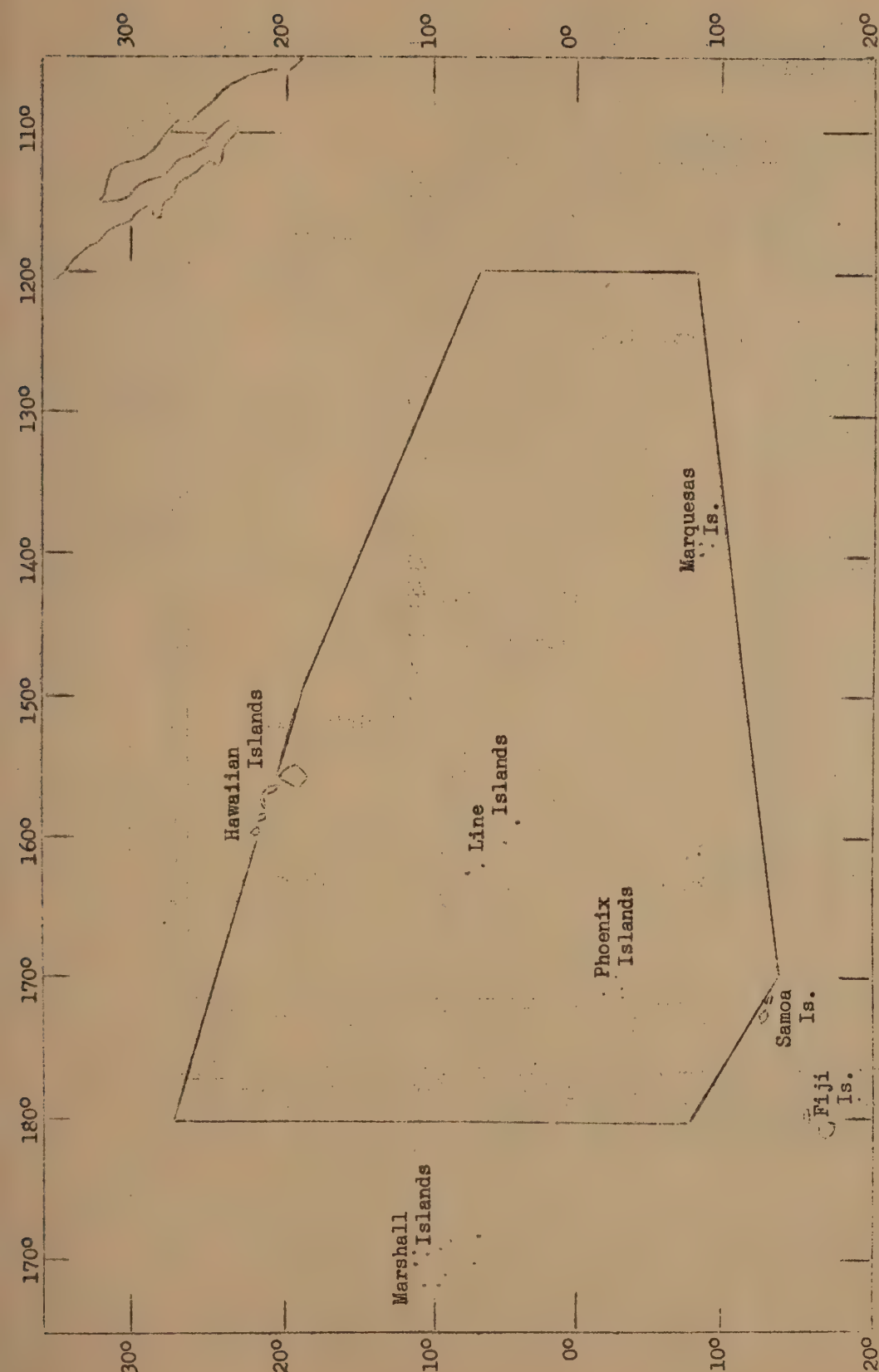

Figure 1.-- Map of the central Pacific showing the boundaries of the area covered in these investigations.

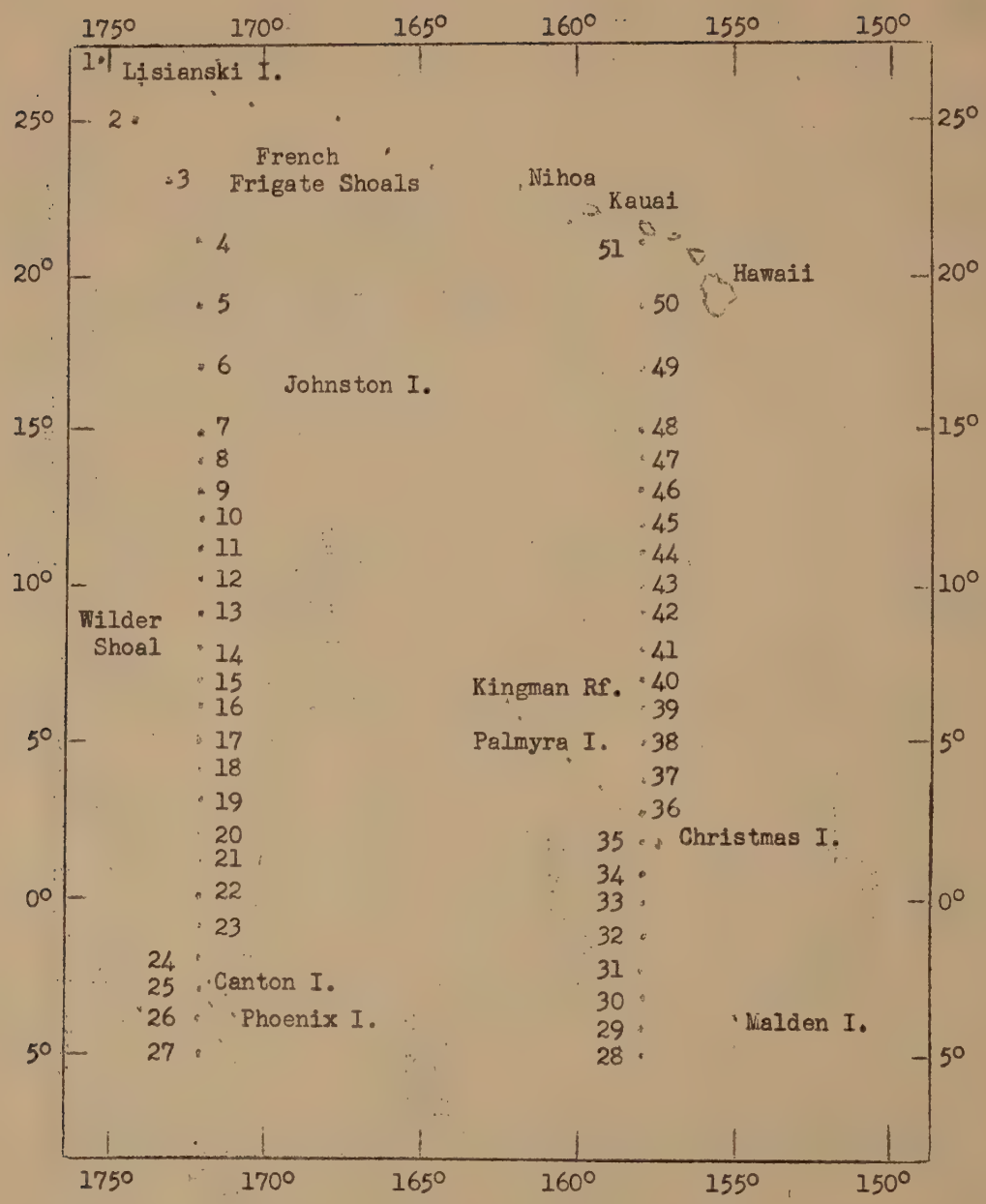

Figure 2.-- Plankton station positions for cruise 5 of the Hugh M. Smith, showing the station pattern of one of the combined hydrographic and plankton cruises.

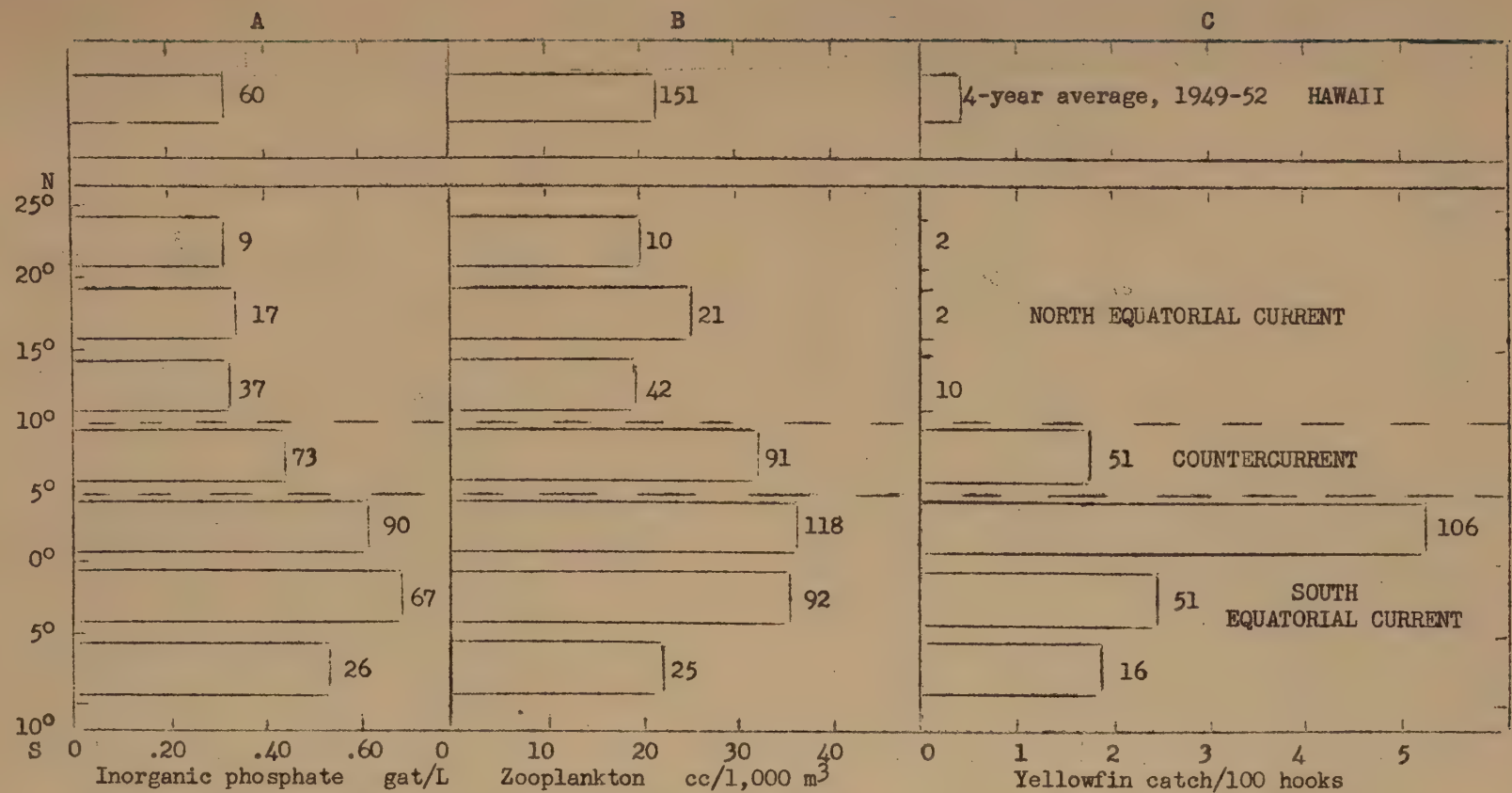

Figure 3.-- Variation with latitude of inorganic phosphate (A), zooplankton abundance (B), and yellowfin tuna catch (C), with the data combined into 5-degree intervals of latitude without regard to longitude and time of year. The approximate boundaries of the major equatorial currents are indicated. (Part A is derived from cruises 2, 5, 8, 11, 14, 15, and 16 of the Hugh M. Smith. Part B is derived from cruises 2, 5, 7, 8, 9, 11, 14, 15, 16, and 18 of the Hugh M. Smith in the equatorial region and cruises 10, 12, 17, and 20 in Hawaiian waters. Part C is derived from cruises 7, 11, and 18 of the Hugh M. Smith; cruises 11, 12, 13, 14, and 15 of the John R. Manning; cruise 1 of the Charles H. Gilbert; and cruise 1 of the Cavalieri. The vessels Smith, Manning, and Gilbert are the property of the U. S. Fish and Wildlife Service. The vessel Cavalieri was chartered by the Government for this one fishing cruise.)

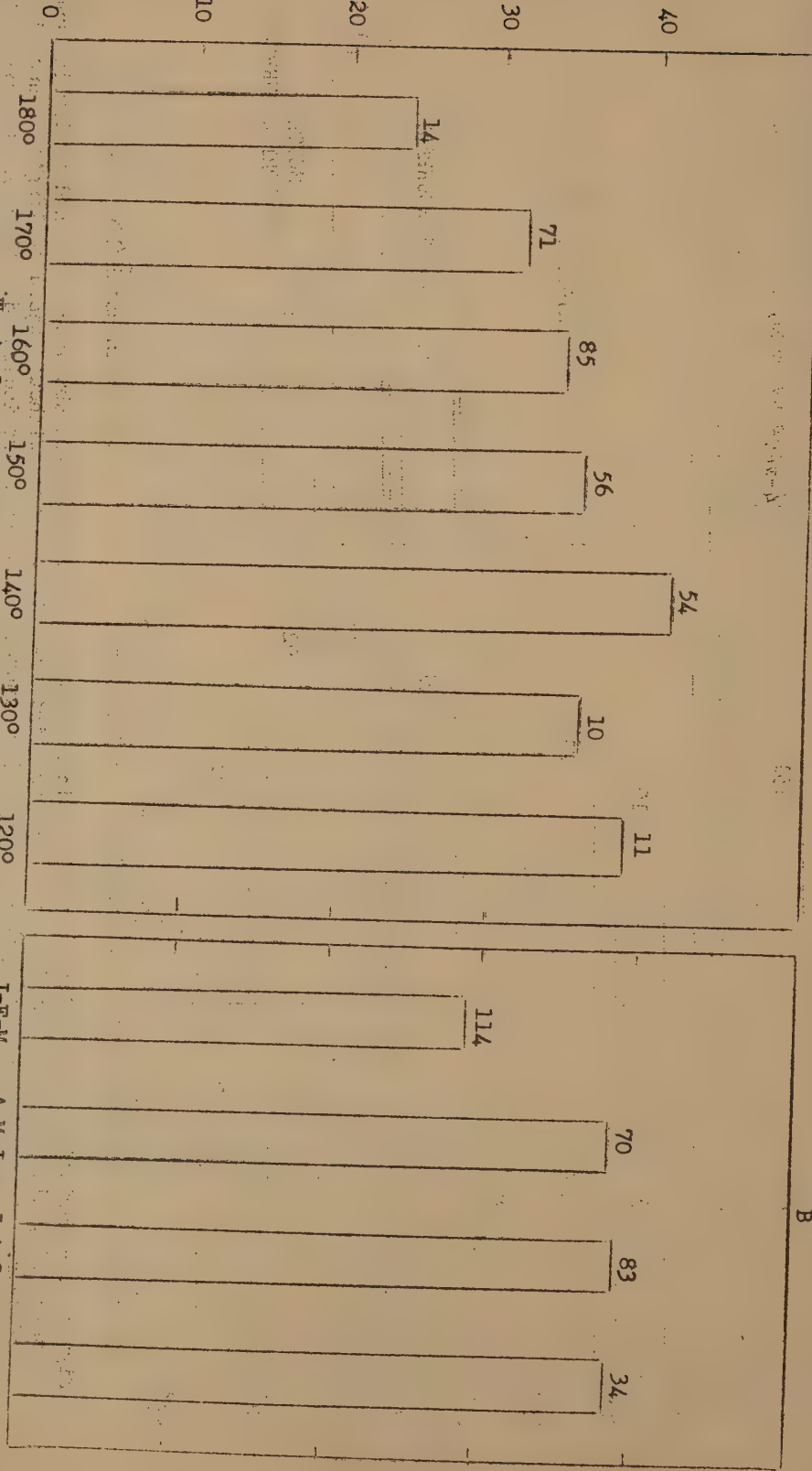

Figure 4.-- Variation in zooplankton abundance with longitude (A) and season (B), for all observations between 9° 59' N. and 40° 59' S. latitude.

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FEEDING HABITS OF THE POND-SMELT, HYPOMESUS OLIDUS AND THE PLANKTON SUCCESSION IN LAKE SUWA (PT.1)

by

Y. Shiraishi *

1. Introduction

2. The Lake Suwa, its limnological features and the biology of Hypomesus olidus

3. Methods of study

4. Feeding habits of the pond-smelt and natural plankton abundance

   i Food organisms found in the stomach
   ii Succession of plankton organisms in the water
   iii Feeding habits and the succession of plankton
   iv Forage ratio

5. Summary

6. Bibliography

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1. INTRODUCTION

In the management of fish resources various biological factors of the species are to be clarified and the scientific knowledges obtained on the factors afford the basic foundation for the procedure of management. Among the various factors the feeding habits of the species is believed to be most significant, and without a knowledge of this factor, the productivity of water will be left in the dark. It is needless to mention that the knowledge on the mechanism of fish production can never be too emphasized for our final object of fisheries management.

The object of the present study is double folds, one aiming at fisheries management and the other at basic biological data.

The food organisms were studied quantitatively as well qualitatively in the fish stomach and also in the lake water, with particular attention to the monthly fluctuation of the phenomena. A study was also made on the diurnal difference in the feeding habits of the species. 1/

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1/ The present report covers the monthly fluctuation of the phenomena. The subject of the diurnal difference will be reported elsewhere.

The planktonic organisms, as said before, were treated both quantitatively and qualitatively. The quantitative analysis of the plankton, under the present limnological practice, has been expressed as the number of individual organisms as well as the weight or volume of the population of the organisms. In the study of feeding habits of a plankton feeder such as the pond-smelt, the numerical presentation of the plankters is not adequate to satisfy our knowledge in which the standing crop of the organisms is necessarily pursued. The presentation of plankton in number involves technically a number of uncertainties, which, however, are far below in the extent compared to those concerned with volumetric presentation of the same organisms.

There are a number of works directed to the food habit of the fish in our country, but most of the studies were limited in its scope to the record of food organisms contained in the stomach of fish. Such records are very valuable and helpful to the solution of different problems, but they are not adequate for the analysis of fish production mechanism in the water.

In the present study, then, assuming the weight of the organisms corresponding to the volume of the same, the former was adopted for the indication of their standing crop, and the weight of individual plankter was obtained through literature, except the chironomid insect, of which the actual dry weight was determined. The weight of the plankton population thus obtained is, of course, purely theoretical, far from the presentation of actual figure, and this was definitely confirmed in the course of the study. Then, the weight of any plankton population was always expressed by the percentage of its occurence among the total plankton communities whether dealt with in the stomach of fish or in the lake water.

It may be also mentioned that in the present investigation, the term "food habit" was meant to indicate only the status whereby the kind of food organisms found in the stomach of the fish is sought, and no consideration is involved beyond, whereas, the "feeding habit" of fish was interpreted to express, in addition to the status of the food habit, the behavioristic aspects of feeding possessed by the fish.

ACKNOWLEDGMENT

The writer wishes to express his highest appreciation to his fellow workers in the Laboratory, Messrs. Y. Furuta and R. Kitamori for their most helpful assistance rendered in the field at the time of collection of samples. He is also highly indebted to Dr. K. Kuronuma, Director of the Laboratory for his critical perusal of the manuscript.

2. THE LAKE SUWA, ITS LIMNOLOGICAL FEATURES AND BIOLOGY OF HYPOMESUS OLIDUS

The Lake Suwa, 14.65 km.^{2} in surface area, is nearly oblique in shape with shore development calculated at 1.345. The lake is 4.61 m. deep in average with the deepest spot near the center, sounding 6.8 m., and the levelling of the water is partially managed by a dam, which is the sole outlet of the lake, with the range of fluctuation 1 m.; the average lake water level is 759 m. above the sea.

The temperature of water ranges from 0 to 26°C. in the surface and 4 to 22°C. in the bottom, showing the themocline 3 m. in summer and 0 to 1 m. in winter. The transparency is 0.6 m. in summer and 2.5 m. in winter. The oxygen content of the lake water ranges from 4.06 cc. to 9.66 cc. per liter in the surface and 0.08 to 8.24 cc. in the bottom.

The lake, originated by the blockade resulted from landslide, is eutrophic with the highest fish production per unit of area in Japan (866 Kg. per ha. /Nakai & Matsui, 1938/).

The standing crop in the water is calculated as follows (Kurasawa, Kitazawa and Shiraishi, 1952, and others):

Seston .....2.5 (Feb.) to 11.5 (Sept.) mg. per l.
Plankton....3.1 (Jan.) to 55.0 (Sept.) mg. per m^3
Benthos.....2.23 (Sept.) to 14.57 (June) mg. per m^3

The fish fauna of the lake is rich with 18 species as listed below now occurring.

Plecoglossus altivelis, Oncorhynchus rhodurus, Hypomesus olidus, Misgurnus anguillicaudatus, Cyprinus carpio, Carassius carassius, Sarcocheilichthys variegatus, Gnathopogon elongatus, Pseudogobio esocinus, Zacco platypus Tribolodon hakonensis, Parasilurus asotus, Aplocheilus latipes, Gobius similis, Chaenogobius annularis, Pseudoperilampus typus, Rhodeus ocellatus and Anguilla japonica.

The pond smelt, Hypomesus olidus (Family Osmeridae) known as "Wakasagi" is one of the important food fish produced in Japanese lakes and swamps. The total catch of the fish in 1949 was 3,367 tons in the country, where the catch of freshwater species is given, in the order of amount, as carp, wild gold-fish, salmon, ayu, eel and the present species. In Lake Suwa, with the total catch of fish and clams amounting 469 tons per year, the wakasagi is placed on the top (37%). The species occurs in Hokkaido southward to L. Kasumi along the Pacific Coast of Honshu and to L. Shinji on the sea of Japan Coast, dwelling in the lakes and lagoons connected to the sea. In addition to the natural distribution, the wakasagi are now commonly seen throughout the country in lakes and swamps as the result of artificial stocking.

The life span of this osmerid fish is 3 to 4 years if the water is favorable, but in most of the lakes where the fish naturalized after the stocking, the fish mostly succumb after the spawning which is seen at the end of one and two years after hatching. In Lake Suwa more than 98% of population is one year old, when they lay eggs, from February to April, ascending the streams which flow into the lake.

The pond smelt is a plankton feeder, as generally believed, and the study of feeding habit attempted in the past reveals that the species is definitely called a plankton feeder. Reviewing the 11 such studies carried on 7 different lakes it was found that the following organisms were found in the stomach:

Cladocera (11 cases), Copepoda (8), Malacostraca (7), Rotifera (11), Diptera (5), Ephemeroptera (3), Fish (2), Algae (6) and other organisms (3).

The rate of growth in this species is variable, depending on the ecological set-up of the body of water, and the measurements made monthly in L. Suwa as shown in Table 1.

Table 1. Monthly growth of H. Olidus in L. Suwa. Figures show the average in the specimens collected monthly, 1950 & 1951

Month	Number of specimens	Body length in cm.	Weight in gr.	
			Male	Female
May	70	2.55	0.15	
June	344	3.60	0.27	
July	205	4.60	0.60	
Aug.	118	5.62	1.55	
Sept.	172	6.67	2.83	
Oct.	50	7.72	4.75	
Nov.	120	8.78	6.83	7.05
Dec.	124	9.62	8.37	9.47
Jan.	10	10.05	10.12	11.65
Feb.	21	10.12	11.15	13.20
Mar.	48	10.15	11.05	13.45

3. METHODS OF STUDY

The examination of the stomach content of the fish and the analysis of the plankton in the water yielded two basic data. Naturally, these two data should be obtained simultaneously from the lake. Also it is felt reasonable to treat these two factors in terms of long and short duration of time, in other words, to treat them seasonally as well as diurnally. In the long term analysis of the data we may be able to see the food requirement of the fish species in the water with its relation to the quality of plankton production, while in the short term or diurnal analysis, we will see the actual feeding habit of fish related to the timely occurence of plankton in the water.

Keeping these facts in mind, the collection of samples (both fish and plankton) was made as explained below.

A. Fish

In the collection of fish two kinds of gear were used: cast net and gill net with meshes of silk and amiran. The cast nets used measure 7 m. long with the area of spreading in the water about 35 m^2, the mesh, however, varied from 0.8 to 1.17 cm. in stretched length according to the size of the fish.

The gill net, specially designed for the purpose of the present investigation, is quadrangular (2 x 6 m.) and lowered into the water lengthwise; the float, attached to the top of the net, is a bamboo stick 2.2 m. long with diameter of about 5 cm., and another 6 bamboo sticks of same length, but with diameter of 3 cm., were tied to the entire netting below the float-stick at intervals of one meter. To the lowermost stick, which was tied to the bottom of the netting, several pieces of lead were attached to keep the net in vertical position in the water; however, the other six bamboo sticks were tied to the net only at their two ends, in order to keep the net stretched in the water. The mesh of the gill net is also 1.17 to 1.78 cm. in stretched length. The gill net was used in the diurnal study of fish and the latter were checked as to their number and the position on the net.

The gill net, used in order to collect the fish samples in terms of diurnal change, was operated in the water near the center of the lake. The operation was conducted on 2 days as shown in Table 2, and in each operation the net was handled every three hours in 24 hours. The collection of fish by means of cast nets was made monthly in the wide stretch of deep areas in the lake, and the date of collection is also given in Table 2.

Table 2. Collected data of H. olidus in L. Suwa, giving the date, method and number of fish specimens, together with the data of plankton sampling.

Date	Fish		Plankton	
	Method	Number	Vertical collection by siphon	Surface collection by bucket
1949				
Aug. 18	Cast net	93		+
Sept. 22	Gill net	148	+	
Oct. 8	"	99	+	
1950				
June 27	Cast net	863		+
July 25	"	406		+
Aug. 17	"	96		+
Sept. 1	"	104		+
" 10	"	66		+
" 20	"	20		+
" 21	"	39		+
" 22	"	55		+
" 29	"	93		+
Oct. 10	"	22		+
" 24	"	55		+
Nov. 20	"	20		+
Dec. 5	"	3		+
" 18	"	91		+
1951				
Jan. 15	Gill net	11		+
Feb. 8	or scoop-	38		+
Mar. 6	net	12		+
" 11	"	18		+
" 21	"	11		+
" 22	"	38		+
Apr. 15	Cast net	20		+
May 15	"	20		+
Total		2441		

1) Two collections in 1949 and 1950 were made on diurnal basis, but rest of the collection attempted without regard to hours.
2) The collection in early 1951 was made by means of gears commercially used.

The fish specimens, obtained either by gill net or cast net, were immediately transferred into formalin of 10% concentration. The formalin-soaked specimens were brought back to the laboratory, and

the routine measurements of length (body length) and weight were made on each specimen. The stomach (from cardiac part to pyloric part), which was easily recognised from the other parts of the digestive organ, was dissected out and the food content was weighed. The content was next spread on a slide-glass and quantitative as well as qualitative examination of the food organisms were made under a microscope.

B. Plankton

The plankton was collected, as explained below, simultaneously with the fish sampling. However, in the analysis of plankton data elucidating its seasonal as well as diurnal fluctuations and its relation to fish feeding habit, the result of the writer's former study (Kurasawa, Kitazawa and Shiraishi, 1952 a, b) was applied. Especially the data on the seasonal change of plankton fecundity were mostly derived from the study above-mentioned.

As shown in Table 2 the plankton samples were collected at the same time with the catch of fish specimens. To collect plankton quantitatively the net was not used in the present study; instead, by means of a rubber tube which is lowered to the water of desired depth the lake water was siphoned up. The surface water was drawn by means of a bucket. In each case, the plankton was obtained by filtering the collected water through a small plankton net.

A device, siphon water sampler, was specially designed to siphon up the water at the desired depth: a brass tube (an old fire-extinguisher) 30 cm. long with diameter of 20 cm. closed at one end and with a wire-handle fixed to the open end; a faucet 1.5 cm. in diameter was soldered to the bottom. A small brass valve of frustrum shape is set at the top of the faucet, the valve was partially regulated by hand by means of a string tied to the top of the valve; to the faucet a rubber tube 8 m. long with diameter of 2.5 cm. was connected, and, at its distal end, a T-shaped metal tube was attached; the upper end of the rubber tube towards the faucet was enforced by a coil of wire inside the tube to present the flexure and closing of the tube; the brass tube was graded up to 10 litres.

To use the siphon water sampler, firstly the rubber tube was filled with water; the rubber tube was then lowered to the layer of desired depth by means of a sinker tied to the end of the tube. The brass tube, with frustrum valve pulled up, was then pushed vertically into the surface water, and 10 litres of water siphoned up into the brass tube. This water is poured out. Finally the required water (5 litres in the present study) is siphoned up. The water (5 litres) thus obtained was filtrated through a small plankton net (silk No.25), and the filtrate was treated with 5% formalin. Samples were then brought back to the laboratory and centrifuged (hand-operated), and out of 0.5 cc. of sediment 0.05 cc. was pipetted. The sub-sample was spread on the counting slide-glass (6 x 3 cm.) marked with 1 mm. spaced fine lines, and was examined under a compound microscope.

The surface water sample was drawn up by a bucket, and 15 litres of water were strained through a plankton net in the same way as in the siphon collection. The subsequent procedure was exactly as in the latter case.

C. Benthos

The benthos were not taken into consideration when the fish as well as plankton samples were collected. However, as the analysis of the stomach content of fish was made, it was felt that some of the benthic animals were also playing an important role in the diet of H. olidus. Fortunately the benthos of the lake were studied in the previous year by Kitazawa and Kurasawa (1951) and Shiraishi (M.S.), and the procedure of benthos collection followed by these workers may be briefly mentioned here.

The monthly collection of the benthos was made at 5 selected stations in the lake, using Ekman-Birge's (15 x 15 cm.) and Lenz's bottom samplers. The samples collected were first poured on a screened tray with 1 mm. mesh, through which the bottom deposits were washed out, and the sediments remaining on the tray were preserved in vials with 10% formalin. The materials, thus prepared in the field, were brought to the laboratory and examined.

D. Other data

The temperature of water was examined by means of a reversing thermometer at the time of gill net fish collection. In case of the cast net fish collection the temperature of surface water only was measured.

Together with gill net fish collection the oxygen content of the water was obtained from the samples at intervals of a meter from the surface to the bottom. The water, collected by an ordinary water sampler (600 cc. capacity), was tested by Winkler's method.

The light intensity, which was also studied together with gill net fish sampling, was measured at every hour in 24 hours. The device used was a photocell mounted in a special container (converted from an old pressure-gauge) and a microammeter (both of these instruments were products of Tokyo Shibaura Electric Co.). The photocell was lowered into the water, mounted on the Sechi's disc so as to keep the instrument in the horizontal position.

It may be mentioned that the netting and collectors used in the present study, excepting the photo-electric instruments, were all prepared by the author.

4. FEEDING HABITS OF THE POND-SMELT AND THE ABUNDANCE OF PLANKTON

Before entering the analysis of data a few rods were thought to be added concerning the terminology used in the fish plankton study to follow.

The major food items found in the fish stomach were composed of planktonic organisms in their ordinary sense. The chironomid insect was found to have been eaten in large quantities by the fish, since these animals were also interpreted as a kind of plankton, the term "notoplankton" will be used to denote them. It may be also noted here that some forms of Cyclops and Bosmina, which are generally considered as typical planktonic crustaceans, are found quite frequently in the bottom deposit mixed with other typical benthic animals such as Chironomus and Tubifex.

In the calculation of a standing crop (the total amount on a given date) of the plankton in the water, the weight of an individual plankter was necessarily required. In the present investigation the weighing of plankter was not attempted, but the weight values which had already been obtained by competent planktologists were consulted (Yoshimura, 1937). The chironomids, however, were weighed by the present author. The dry weight of each form of plankters treated here was obtained as follows:

Leptodora	48×10^{-3} mg.
Bosmina	4.1×10^{-3} mg.
Cyclops	4.9×10^{-3} mg.
Diaphanosoma	5.0×10^{-3} mg.
Chironomids	2000×10^{-3} mg.

The writer is well aware that these values of weight of minute organisms may be far from the actual, but, they were applied here as in the usual standing crop study of plankton.

Some of the recent investigations on the feeding habits of fish have shown a tendency towards the objective aspect (Hess and Swartz, 1940; Hess and Rainwater, 1939; Patriarche and Ball, 1949; Hess and Tarzwell, 1942, etc.). The expression of quantitative analysis of food organisms in fish stomach against that of the organisms in the natural water, as advanced by and stressed by the workers noted above, is effected more objectively through the calculation of the "forage ratio". The author, however, does not believe that the forage ratio brings out the full relation between fish and natural food, including availability or preference.

The "forage ratio" (Hess and Swartz, 1940), "availability factor" (Allen, 1942, after Patriarche & Ball, 1949) or "index of food preference" (Shorygin, 1939, after Ricker, 1946) are also proposed indexes to show quantitatively the relation of the density of the food organisms in the stomach of the fish and that in the environment. In any of those indexes, if the ratio of a group of organisms varies significantly from that of other organisms, it is apparent that the former preponderates in the diet of the fish, but it does not show whether this is due to the availability of the organisms or the preference of fish.

Notwithstanding the facts mentioned above, the forage ratio was found, in the present study, to be a useful analytical instrument in the study of feeding habit of the fish. The percentage of the number of organisms as well as the weight of the organisms were reckoned.

i. Food organisms found in the stomach

It is first of all noted that the pond-smelt, Hypomesus olidus in Lake Suwa depend solely on animal food. There were found in extremely small amounts of diatoms in the stomachs examined, but they were negligible. Miyauchi (1934) records some phytoplankton in the stomach of fish collected from Lake Kasumi, but the amount of the organisms was not given.

The animal organisms found in the stomachs of fish are listed as follows:

Trochelminthes:

- Asplanchna priodonta
- Brachionus sp.
- Synchaeta tremula
- Triarthra terminalis
- Keratella cochlearis
- Monostyla lunaris

Arthropoda:

Crustacea

Cladocera

- * Leptodora kindtii
- * Bosmina longirostris
- Bosminopsis deitersi
- * Diaphanosoma brachyurum
- Ceriodaphnia quadrangula
- Chydorus sphaericus
- Alona guttata

Copepoda

- * Cyclops strenuus & nauplius
- Diaptomus pacificus

Ostracoda

- Lynceus sp.

Decapoda

- Paratya compressa (mysis stage)

Insecta

Ephemeroptera

- Epeorus latifolium
- Ehemerella japonica
- Baetis sp.

Diptera

- * Chironomus plumosus
- Orthocladius sp.
- Tanypus sp.
- Chaoborus sp.

Coleoptera

- Agabus japonicus

Arachnida (a form not identified)

Pisces

- Chaenogobius annularis
- Hypomesus olidus (eggs)

The total of 28 forms of these animals possess, by no means, the same diet value to the fish; on the contrary, the forms which are asterisked in the list shown are the most prominent (Table 3).

Table 3. Analysis, by month, of food items found in the stomach of H. olidus in L. Suwa. The figures show the average count and calculation for one stomach, the number of specimens examined given after the name of month, (see text for the weight calculation of food item).
A. Number of individuals and percent in parenthesis. B. Calculated weight (10 mg.) and percent in parenthesis.

Month of collection and the number of fish specimens examined	Bosmina 1/		Leptodora		Cyclops 2/		Diaphanosoma		Chironomids 3/		Others 4/		Total weight of stomach content in mg.	
	A	B	A	B	A	B	A	B	A	B	A	B	Actual weight (wet)	Calculated weight (dry)
1950														
June (278)	18.2 (26.1)	90.3 (0.43)	0.21 (0.2)	98.0 (0.05)	26.9 (31.9)	132.0 (0.63)	3.1 (3.7)	15.4 (0.07)	10.4 (12.4)	20755.0 (98.69)	21.5 (25.6)	27.9 (0.13)	21.13	21,030 x 10^{-3}
July (406)	95.8 (91.0)	493.8 (34.56)	0.95 (0.7)	45.6 (3.19)	4.2 (3.2)	20.6 (1.44)	6.3 (4.8)	31.6 (2.21)	0.4 (0.3)	837.4 (58.60)			32.31	1,429 "
Aug. (96)	19.1 (67.2)	78.5 (5.92)	8.14 (28.6)	390.5 (29.43)	0.5 (1.6)	2.3 (0.17)	0.3 (1.0)	1.4 (0.10)	(1.6)	854.2 (64.38)	0.4 (1.3)		23.05	1,326 "
Sept.(427)	3.1 (13.5)	12.7 (1.87)	8.41 (36.4)	403.1 (58.98)	4.3 (18.5)	20.9 (3.06)	7.2 (31.2)	35.9 (5.26)	0.1 (0.4)	210.8 (30.83)			11.93	683 "
Oct. (176)	36.3 (58.3)	148.9 (3.20)	1.67 (2.7)	80.2 (1.72)	21.2 (34.2)	104.2 (2.24)	0.7 (1.1)	3.4 (0.08)	2.2 (3.5)	4318.2 (92.75)	0.1 (0.00)	0.7 (0.01)	8.94	4,655 "
Nov. (13)	174.1 (15.4)	706.6 (6.0)			955.1 (84.5)	4679.6 (40.4)			3.1 (0.3)	6200.0 (53.60)	0.5 (0.00)	0.5 (0.00)	66.24	11,585 "
Dec. (42)	465.0 (68.0)	1908.5 (18.7)			217.0 (31.5)	1064.2 (10.4)			3.6 (0.5)	7238.0 (70.9)			43.59	10,220 "
1951														
Jan. (11)	1.54 (1.1)	6.4 (0.05)			140.0 (94.7)	687.8 (5.27)			6.2 (4.2)	12363.6 (94.68)			43.00	13,057 "
Feb. (83)	40.9 (35.4)	167.7 (4.10)			69.5 (60.5)	170.1 (8.32)			1.5 (1.5)	1638.5 (87.54)	5.6 (2.6)	11.8 (0.04)	11.84	1,989 "
Mar. (51)	1.22 (3.4)	5.0 (0.09)			11.5 (71.5)	56.7 (2.28)			6.1 (7.5)	3757.5 (97.63)	6.05 (17.5)		20.26	3,819 "
Apr. (21)	5.71 (5.1)	23.4 (1.48)			105.0 (94.4)	515.9 (32.51)			0.5 (0.5)	1047.6 (66.01)			10.83	1,587 "
May (20)	1.50 (78.5)	6172.5 (50.70)			408.7 (21.3)	2002.9 (16.44)			2.0 (0.2)	4000.0 (32.86)			75.50	12,175 "

1/ Including also Bosminopsis.
2/ Including both young and adult.
3/ Chironomus, Orthocladius, Tanypus and Chaoborus are included.
4/ Many forms included. See text.

The rotifers, though not shown in the table, do appear in the stomachs of young fish measuring about 3 cm. in body length during the month of June (25.6%) only when the pigment formation is complete. Sato (1952) recorded the same phenomenon in his experiment.

The eggs of the same species were also found in the stomachs in February (0.5% in number of total organism) and March (16.9%) when the spawning takes place but not in other months; the fish had swallowed the eggs without doubt, but whether the fish had preference on the eggs, or if they were eaten deliberately, are not clear.

The seasonal change of the food habits of the fish (Table 3) does by no means correspond regularly to the progress of months or the growth of fish as it would have been expected. These observations may be affected by the incompleteness of sampling of fish as to the method, locality and time, and also by the rather remarkable individual variation in food habits. However, we will be able to believe that 1) Bosmina forms a major food item of the species but abundantly eaten especially in the months of summer extending from July to October, 2) during the months of November to April Cyclops are mainly eaten, 3) Leptodora and Diaphanosoma do occur but only in the later summer, 4) the chironomids are eaten throughout the year, but the amount varies monthly, and 5) the general food habits of the species is different between summer and winter and more or less clear transition of the diet seems to be around the month of October.

The foregoing analysis of the food habits of the pond-smelt was based on the bulk of food organisms which occurred in the stomach. A similar analysis was then made on the basis of frequency method in which the number of stomach samples in which each food item occurred, are counted and converted into percentage of frequency (Table 4).

Table 4. Frequency of ocurrence of food organisms in stomachs. Figures showing the number and percentage in parenthesis of stomach samples in which each food item occurred; the occurrence further broken into percentage (0 to 100). In this analysis minor food organisms are excluded.

Form of organisms	Occurrence of organism in %	June (472)	July (179)	Aug. (17)	Sept. (221)	Oct. (46)	Nov. (40)	Dec. (30)	Jan. (10)	Feb. (24)	Mar. (32)	Apr. (11)	May (16)	Total in a year
		Month and the number of stomach samples												
Leptodora	80-100			10 (58.8)	41 (18.5)									51 (4.56)
	60- 80			1 (5.9)	24 (10.9)									25 (2.24)
	40- 60			2 (11.8)	19 (8.6)	2 (3.0)								23 (2.06)
	20- 40	2 (0.4)	2 (1.0)	1 (5.9)	25 (11.3)	4 (6.0)								34 (3.04)
	0- 20	470 (99.6)	177 (99.0)	3 (17.6)	112 (50.7)	60 (91.0)	40 (100)	30(100)	10(100)	24(100)	32(100)	11 (100)	16(100)	985 (88.10)
Bosmina	80-100	42 (8.9)	124 (69.3)	6 (35.3)	43 (19.5)	21 (32.0)	4 (10)	5(16.7)		13(54.1)	3(9.4)		9(56.2)	270 (24.05)
	60- 80	21 (4.5)	25 (14.0)	1 (5.9)	32 (14.5)	13 (19.8)		1(3.3)					3(18.8)	96 (8.57)
	40- 60	46 (9.7)	10 (5.6)	3 (17.6)	21 (9.5)	7 (1)				5(20.9)				92 (8.23)
	20- 40	78 (16.5)	6 (3.4)	3 (17.6)	24 (10.9)	9 (14.1)	5(12.5)			1(4.1)	1(3.1)		2(12.5)	129 (11.55)
	0- 20	285 (60.5)	14 (7.4)	4 (23.6)	101 (45.7)	16 (24.0)	31(77.5)	24(80.0)	10(100)	5(20.9)	28(87.5)	11 (100)	2(12.5)	531 (47.60)
Cyclops	80-100	41 (8.7)			2 (0.8)	1 (1.5)	26(65.0)	25(83.5)	7(70)	6(25.0)	19(59.4)	10 (91.0)		137 (12.25)
	60- 80	38 (8.1)	2 (1.0)		8 (3.6)	1 (1.5)	5(12.5)	4(13.2)	2(20)	1(4.1)	1(3.1)	1 (9.0)	2(12.5)	65 (5.82)
	40- 60	18 (3.8)	1 (0.5)		11 (4.9)	4 (6.0)	1(2.5)			3(12.4)	1(3.1)		3(18.8)	42 (3.76)
	20- 40	43 (9.1)	6 (3.4)		25 (11.3)	4 (6.0)		1(3.3)		1(4.1)	3(9.4)		6(37.5)	89 (7.95)
	0- 20	332 (70.5)	170 (95.1)	17 (100)	175 (79.2)	56 (85.0)	8(20.0)		1(10)	13(5.4)	8(25.0)		5(31.2)	785 (70.22)
Chironomus	80-100	95 (20.1)			1 (0.4)	4 (6.0)	6(15.0)				4(12.5)	3 (27.2)		113 (10.10)
	60- 80	32 (7.8)				1 (1.5)		1(3.3)	1(10)		3(9.4)			38 (3.40)
	40--60	25 (5.3)			1 (0.4)	1 (1.5)			1(10)		1(3.1)			29 (2.60)
	20- 40	29 (6.2)				3 (4.5)		2(6.7)		1(4.1)	2(6.2)	1 (9.0)		38 (3.40)
	0- 20	291 (61.8)	179 (100)	17 (100)	219 (99.2)	57 (86.5)	34(85.0)	27(90.0)	8(80)	23(95.9)	22(68.8)	7 (63.8)	16(100)	900 (80.50)
Others	80-100				8 (3.6)					2(8.2)	6(18.8)			
	60- 80				4 (1.8)					1(4.1)	1(3.1)			
	40- 60			2 (11.8)	8 (3.6)					1(4.1)				
	20- 40			1 (5.9)	4 (1.8)						7(21.9)			
	0- 20			14 (82.3)	197 (89.2)					20(84.6)	14(67.2)			

1) Diaphanosoma brachyurum

a) Egg of H. olidus

In this way it is noticed that the chironomids, as stated above, appear throughout the year, which however, does not mean that these organisms are fed by the fish with any high preference. When we compare the number of samples of fish (stomachs) by month with reference to the nature of the food as: food consisting of organisms other than chironomids, food consisting of chironomids only and the food consisting of both chironomids and others, we have observed that: in June 77.8% had only non-chironomids food, 2.7% only chironomids and 19.5% mixture of these organisms among 863 stomachs examined, in the same way each month showed, July (81.5, 0, 18.5 in 223) August (96.9, 0, 3.1, 96), September (93.9, 0, 6.1, 357), October (20.8, 0, 79.2, 77), November (85.8, 0, 14.2, 63), December (100.0, 0, 32), January (9.6, 0, 90.9, 11) and February (53.8, 0, 46.2, 52). It is apparent that the pond-smelt which had only chironomids in the stomach were very rare (only 23 among 1873 fish), and found only in the month of June. In Table 4 the occurrence of each major organism was tabulated in further detail.

The seasonal change of the food habits explained above was interpreted on the data of the number of individual organisms. But when the quantity of the food organisms is expressed in weight and the data are analysed, the food habits of the species show quite a different picture (Table 3, B).

The nutritive values of the various items assume a different proportion in the gravimetric analysis. The chironomids (Chironomus and Orthocladiinae) are definitely the major food item of the fish throughout the year, though there are monthly fluctuations observed in its percentage against the total stomach content. Following the chironomid insects, the cladocerid Leptodora occupy the next place, but in almost the same quantity as the former during the month of August and September. The appearance of Cyclops and Bosmina is nearly to the same extent as in the case of numerical analysis. These facts are obvious from the differing weights of the organisms.

The total amount of stomach content has an important bearing in the present study. Thus the rates of feeding in the different months or growth ages of the fish have to be understood. It is difficult to determine the daily requirement of food for a fish, at least in the present study. The amount of food found in the fish stomach reflects only the condition at the time of collection. Moreover, the feeding habits of the species vary significantly by the hour within a day, so that the exact amount of food found in the stomach, for any comparison from month to month could not be obtained for our specimens, which were mostly collected without regard to any definite hour of the day.

Then, in order to answer the question raised above, the specimens which were collected during the hours 1500 to 2100 were picked up from the whole collections, and the amount of the stomach content was checked against the total weight of the fish.

The weight or volume of stomach content, obtained from the selected specimens as indicated above, varies significantly within the year or relating to the growth of the fish (Table 3). The absolute weight of the content ranges from 10 mg. in the least to 80 mg. in the highest per fish, and the fish eat extensively toward and during the spawning period (October to January) and again in May.

The young fish show higher weight of consumed food than the grown-up fish, and this tendency was presented as follows: June (the fish weigh 0.27 gr. and the stomach 7.8% of the former), and in the

same way July (0.60 gr., 5.5%), August (1.5 gr., 1.5%), September (2.8 gr., 0.4%), October (4.75 gr., 0.2%), November (6.9 gr., 0.9%), December (8.9 gr., 0.5%), January (11.3 gr., 0.4%), February (12.2 gr., 0.1%), March (12.2 gr., 0.2%), April (12.2 gr., 0.1%) and May (12.2 gr. 0.6%). This fact is believed to be a common phenomenon observed in many species of fish.

ii. Succession of plankton organisms in the water

As pointed out before (pp. 7 and 13) the chironomids (larvae, pupae as well as adult) which are major food items of the species were also treated as a plankton (metoplankton) in the present discussion. The typical planktonic crustaceans such as Bosmina and Cyclops, as noted already (p. 7), often enter into the benthos. The plankton data introduced here represent but those in the deeper regions of the lake where the pond-smelt spends most of its life. The data of plankton succession obtained in the coastal (or shallower) region are different from that of the deeper region, and were excluded from the present plankton analysis.

The succession of the plankton in the lake is partly shown in Table 5, in which only those forms which were found in the stomach of the pond-smelt are treated. However, the general picture of the plankton succession in the water is quite different, for instance, many forms of rotifers are extremely abundant in the water compared to the crustaceous plankton, but the Trochelminthes are eaten by the fish only in the month of June.

Limiting our analysis only to organisms which are used by the fish as food it is noticed that Cyclops (including the nauplius) and Bosmina swarm in the water twice a year, i.e. spring (March and April) and summer (August), which is a common phenomenon observed in most of our inland lakes. Such facts were brought up from the actual number of plankters counted in an unit of water. But, the succession of the food plankton shows a different picture when the relative number of plankters in an unit of water is compared. The copepod Cyclops including nauplius grow abundantly in March and October, whereas, Bosmina are relatively abundant in August, December and May. The chironomids, as far as the number of individuals are concerned, appear throughout year with almost no monthly fluctuation. Diaphanosoma are quite few in actual number, but its relative abundance against other forms of plankton is significant in December.

The food plankton organisms, now converted into the dry weight (Table 5, B) in place of the number of individuals, show again a quite different picture of succession in terms of relative abundance in the water. The chironomids insect swarm overwhelmingly throughout the year keeping 80% level with an exceptional drop (still 50%) in September. The crustaceans referred to Bosmina, Cyclops put together occupy 50% abundance in September, but in the rest of the months of the year they show less than 20% abundance, except in May when Bosmina rise to 25%.

The rotifers in the lake water are abundant as stated before as far as the number of individuals is concerned, but the amount in weight appears to be extremely low, because of their size (calculated dry weight 0.15×10^{-3} mg. to 1.9×10^{-3} mg., Yoshimura, 1937).

iii. Feeding habits and succession of plankton

In the preceding sections we have been able to clarify how the pond-smelt obtained its foods and the appearance of the latter in the lake.

Table 5. Monthly succession of the number of plankton in L. Suwa, 1948-1949. The samples were collected by vertical siphon method near the center of the lake; thefigure showing the number of individuals and calculated weight in the water of 1 cubic meter. The forms of plankton limited only to those which were found in stomach of H. olidus. A. Number of individuals and percent in parenthesis. B. Calculated weight (10-3 mg.) and percent in parenthesis.

Month	Bosmina 1)		Leptodora		Cyclops 2)		Diaphanosoma		Chironomids 3)		Others 4)		Total calculated (dry) weight of plankton in the unit of water
	A	B	A	B	A	B	A	B	A	B	A	B	
1948													
June	600 (1.0)	2,400 (0.01)			6,800 (10.7)	1,960 (0.01)			11,968 (18.9)	23,936,000 (99.97)	43,800 (69.4)		23,942,320 x 10^{-3} mg.
July	10,800 (54.5)	44,280 (1.51)	600 (3.0)	28,800 (1.00)	7,000 (35.3)	34,300 (1.17)			1,408 (7.1)	2,816,000 (96.61)			2,923,380 "
Aug.	14,600 (45.3)	59,860 (4.02)	600 (1.9)	28,800 (1.34)	10,800 (33.4)	52,920 (3.55)	5,600 (17.4)	28,000 (1.88)	660 (2.0)	1,320,000 (88.61)			1,489,580 "
Sept.	50,800 (48.6)	208,280 (19.93)	1,040 (1.0)	49,920 (4.78)	51,800 (49.2)	253,820 (24.29)	1,000 (1.0)	5,000 (0.47)	264 (0.2)	528,000 (50.53)			1,045,020 "
Oct.	8,000 (34.2)	32,800 (2.31)			13,614 (58.4)	66,856 (4.71)	200 (0.9)	1,000 (0.07)	659 (1.6)	1,312,000 (92.43)	1,400 (5.9)	6,860 (0.48)	1,419,516 "
Nov.	9,200 (50.5)	37,720 (2.88)			7,800 (42.8)	38,220 (2.91)	600 (3.3)	3,000 (0.23)	616 (3.4)	1,232,000 (93.98)			1,310,940 "
Dec.	18,600 (72.9)	76,260 (6.49)			6,000 (23.5)	29,400 (2.51)			484 (2.0)	968,000 (82.48)	400 (1.6)	250 (8.52)	1,173,660 "
Jan.	2,044 (30.1)	8,380 (0.84)			3,664 (54.0)	17,954 (1.81)			484 (7.1)	968,000 (97.25)	600 (8.8)		994,334 "
Feb.	374 (4.5)	1,533 (0.09)			7,766 (94.4)	38,053 (2.23)			833 (1.1)	1,666,000 (97.68)			1,705,586 "
Mar.	44 (0.1)	180 (0.01)			80,684 (98.6)	395,352 (15.72)			1,060 (1.3)	2,120,000 (84.28)			2,515,532 "
Apr.	5,200 (1017)	21,320 (0.53)			41,000 (85.2)	200,900 (5.05)			1,980 (4.1)	394,000 (94.42)			3,982,220 "
May	146,400 (94.9)	600,240 (28.78)			6,800 (4.4)	33,320 (1.60)			726 (0.5)	1,452,000 (69.92)	200 (0.2)		2,085,560 "

1) Including also Bosminopsis.
2) Including both young and adult.
3) Chironomus, Orthocladius, Tanypus and Chaoborus are included.
4) Many forms included. See text.

The pond-smelt, H. olidus is called a species of plankton feeder (p. 3) and our examination confirmed the fact in Lake Suwa. Throughout the year the fish are mostly found in the deep region of the lake where also the plankton abounds, thus the fish do not have to perform any large scale feeding migration. Also the pond-smelt is practically the only deep water plankton feeder in this lake, without any competiters. There are other species of fish which also feed on the plankton organisms in the water, especially Bosmina, Cyclops and the chironomids. These organisms dwell in the shallower water or closer to the lake shore, and naturally the fish eating these organisms are restricted to the same region of the lake as their usual habitat. In addition the amount of planktonic organism consumed by these fish are only a fraction, compared to that sought by the pond-smelt.

The pond-smelt starts its life cycle in the winter months and the larval fish seem to start extensive feeding from early March to April. In this same period the rotifers are very abundant in the water, naturally, forming a main diet of the larval fish. This fact was not confirmed in the present investigation, but the stomach content of fish (especially of smaller ones) in June will justify the above assumption. Towards the winter months (November to January of the following year) the fish move to deeper layers of water and during the ice-frozen period (January and February) they are found mainly in the bottom water. This habit of the fish is interpreted as the adaptation to the water temperature and preliminary behaviour prior to spawning migration. Concurrently the planktonic organisms especially Bosmina, Cyclops and the chironomids which are the only available food items in this period are more abundant in the lower layer of water. It is natural to see the chironomids at the bottom, but also Bosmina and Cyclops are found in the bottom bed of the lake (Kitazawa & Kurasawa, 1951).

Two cyclic abundances of plankton are witnessed in March and September in this lake. At the time of vernal swarming of plankton the fish are still in larval stage, and the fish prey mostly on the rotifers, so that other plankters are not fully utilized. At the time of fall, similarly, the fish does not consume much food organisms compared to other parts of the year. It is very interesting to see, in this respect, the pond-smelt in the lake eat less than when the food organisms are more abundant; in other words, the amount of food consumed by the fish is governed by the physiological demand of the latter.

The planktonic crustacean Bosmina appears more abundantly in the lake water from early summer to fall, but the fish feeds on the same organism more abundantly during the summer months. This probably attributed to the fact that the fish changes its main diet from Bosmina to Cyclops in fall and winter, and the latter becomes the major food item in the spring months up to April.

The larger planktonic animals Leptodora and Diaphanosoma, as in other lakes of Japan, appear only for a limited time, (August and September). It is then natural that these organisms form the major food items of the fish in these two months. The abundance of these organisms in the water is not necessarily high in percentage compared to smaller plankton, Bosmina and Cyclops, suggesting that the fish perfers the larger organisms when the organisms of varied size are available in the water. This is confirmed by the fact that Leptodora is eaten more than Diaphanosoma, the former about ten times larger than the latter.

It has been pointed out before that the rotifers, which are found in the water nearly throughout the year, are eaten only by larval fish in the months of April to June. The grown-up pond-smelt are not interested in this very small plankton. The higher preference for rotifers shown by the larval fish seems to be correlated with the earlier spring swarming of the rotifers than that of other plankters.

The midge larvae together with Tubifex, are the main organisms constituting the benthos of the lake, and they are also found most abundantly in the fish stomach as far as the volume is concerned. However, the number of the organisms is relatively very few in the lake water as well as in the fish stomach. Feeding on this large sized food item is found only in a few pond-smelt. Indeed, the number of fish which had the chironomids only in the stomach was only 23 (or 1.25%) against 1873 fish examined. The organisms are found in the water nearly throughout the year without any significant fluctuation, but the number of the animals found in the fish stomach is higher in winter (January to March), later spring (June) and fall (October and September). This fact will show that the chironomids are more easily obtained by the fish in these months than in others. The chironomids emerge from larval stage in the bottom mud to pupae and then to adult in the column of water and the emerging takes place in June and in September-October in the lake. This life cycle of the midges corresponds to the feeding habit of the fish as far as this organism is concerned. The animals found in the stomach in these months are mostly in the stages of pupae and adult (just hatched out).

This fact, however, does not explain the high preference for chironomids seen in the winter months when the organisms are not in emerging stage. In this respect we are not in a position to give a reasonable interpretation, but it may be noted that the fish, at this time, swim near the bottom.

iv. Forage ratio

As stated before the writer found that the "forage ratio" proposed by Hess and Swarz (1940) was helpful within limits to determine the relation existing between the fish and the food organisms. The "forage ratio", as defined by these authors, is a ratio of the percentage of occurrence of an organism in the population to its percentage of occurrence in the stomach of the fish. In the numerical index expressed by the forage ratio, two biological factors are believed to be involved--preference and availability. However, the definitions of these two terms may be extremely difficult to be given, because the biological phenomena expressed by these terms are not clearly understood in the present state of our knowledge. The writer proposes the following tentative explanation of these terms:

Availability--the status of food organisms in the water with reference to their physiological, ecological and morphological conditions.

Preference----the status of the fish towards the food organisms in the water within the limits of availability.

The two terms then seem to express the same and a single biological phenomenon shared by fish and food organisms, and the forage ratio will indicate quantitatively the complex of this biological phenomenon. Several biological indexes proposed to express the same phenomenon are found in the literature as "Index of food preference" (Shorygin, 1939, after Ricker, 1952), "Index of availability and desirability" (Komarova, 1939, after Ricker, 1952), "Availability

factor" (Allen, 1942, after Patriarche and Ball, 1949), etc. All these indexes aim at the solution of the same biological relation between fish and food organisms.

Table 6. The forage ratio observed in H. olidus in L. Suwa. Calculation based on the data given in Tables 2 and 3.

Month	Bosmina		Leptodora		Cyclops		Diaphanosoma		Chironomids	
	A1)	B2)	A	B	A	B	A	B	A	B
June	26.1	43.0			2.98	63.0			0.65	1.0
July	1.67	2.4	0.02	3.5	0.09	1.3			0.04	0.7
Aug.	1.48	1.5	15.05	2.2	0.05	0.05	0.06	0.05	0.80	0.7
Sept.	0.278	0.09	36.4	12.3	0.38	0.1	31.2	11.2	2.0	0.6
Oct.	1.71	1.4			0.586	0.5	1.2	1.1	2.87	1.0
Nov.	0.069	2.85			2.24	13.9			0.09	0.54
Dec.	0.93	2.88			1.34	4.14			0.3	0.86
Jan.	0.036	0.06			1.75	2.9			2.4	1.0
Feb.	7.87	45.60			0.64	3.7			1.36	0.9
Mar.	34.0	12.9			0.73	0.2			5.27	1.2
Apr.	0.47	2.8			1.11	6.4			0.54	0.7
May	0.83	1.8			4.35	10.3			0.46	0.5

1) A "forage ratio" calculated as the percentage of the number of organisms in the stomach divided by the same in the water.
2) B "forage ratio" calculated as in A, instead of the number reckoning the weight.

In the calculation of this ratio we have used both the number of organisms and the weight of organisms to express the percentage (Table 6). The forage ratio thus obtained in two ways, does not necessarily correspond, as expected, and they are also found to fluctuate but in different trends. The two kinds of forage ratio, then, were analysed carefully, but the writer failed to find which one represents the true picture of the forage ratio better. However, it may be stated that when the percentages treated in the calculation are higher, the trend of each forage ratio index is better corresponding to the succession of food organisms in the water as well as to the occurrence of food organisms in stomach, and also that the index seems to be valid within the limit whereby they are expressed as integer or fraction, or more than one or less than one. The numerical differences within the integers or in fractions were found to be non-significant.

In Table 6 we will see that the two kinds of forage ratio calculated here show nearly the same trend when its values are higher as in Leptodora and Diaphanosoma as well as Bosmina in mid-winter. In Cyclops and chironomids the two values are conflicting with each other, though, it might be more strongly reflected by the statistical significance (very few in number of representing specimens) in the latter. We will also see (Table 6) that the forage ratio is often calculated as infinitive or zero, and these figures are reasonable at least mathematically. But the ratio expressed by these figures shows only improbable extremes; the infinitive forage ratio will tell that the non-existing organisms in the water were eaten by fish, and this fact does not show that fish has infinitive preference on the organisms; if the forage ratio is zero it is self-evident that the ratio has no meaning. It is also to be observed that no planktonic forms in the water become zero percent in their relative abundance.

In a careful check of the forage ratio as to its periodical fluctuation we found unreasonable relation between the ratio and the actual occurrence of the organisms in the water. For instance the important food organism, Bosmina is abundant both in water and fish stomach during the months of July to December, but the forage ratio in the same duration is extremely low. A similar tendency is also seen in Cyclops. On the contrary, in the two organisms Leptodora and Diaphanosoma the forage ratio positively corresponds to the occurrence of animals in the water.

Summary

1. The feeding habits of H. olidus was studied in the year 1951 referring to the succession of plankton in Lake Suwa, Nagano Prefecture, and the object of the study was directed to the filling of a gap in the information on the food-chain in the water as well as to obtaining the basic knowledge on which the management of the species could stand.

2. The pond-smelt, usually with only one year of life span is economically the most important species, the annual catch amounting to one-third of the total fish production in the lake. The Lake Suwa is 14.65 m. in surface area with the average depth of 4.61 m., and 18 species of fish dwell in this eutrophic lake.

3. Samples of fish totalling 2,441 were collected monthly by cast net and gill net. The content of the stomach of each sample was examined qualitatively and quantitatively.

4. The pond-smelt in the lake was found to feed on 28 forms of both planktonic and benthic animals, of which Bosmina, Cyclops, Leptodora and Diaphanosoma were major items of food. Thus, the pond-smelt, H. olidus may be said to be a plankton feeder.

5. In the summer months, June to September, the fish was seen to eat more Bosmina than others, and in winter, September to April, Cyclops was the major food item, whereas the macro-plankton, Leptodora and Diaphanosoma were eaten abundantly in August and September. The midge larvae Chironomus were eaten throughout the year, but they appeared in the fish stomach more abundantly in the months of June and October and during the winter months; the chironomid insect emerges in these two months from larval form to pupae and adult; the fish tends to dwell near the bottom during the winter months.

6. By weight, Bosmina and Cyclops were found to be much less significant than when they were considered numerically. The macro-plankton Leptodora and Diaphanosoma, however, did not lose the significance whether expressed in number or in weight. The chironomids, occupied 80% of stomach content in weight, probably forming valuable nutritive element in the diet.

7. The amount of food taken by the fish varies from 10 to 80 mg. at a time, and they are seen to eat more before the spawning season while the survivors after spawning continue to feed subsequently. The amount of food expressed in percentage of body weight is extremely high when the fish is in the juvenile stage, but it decreases with the growth of the fish.

8. The plankton of the lake showed spring and fall swarming in the year as in other lakes in Japan.

9. The amount of stomach content did not necessarily correspond to the abundance of plankters in the water; in Bosmina and Cyclops, the former is eaten more in summer than in spring and the latter more in winter than in fall. In the two forms, Leptodora and Diaphanosoma the preference of the fish on these forms coincided in time with the swarming of the organisms. These facts will suggest that the fish take the food organisms according to their own physiological demands, and the requirement does not depend on the abundance of the food. The rotifers are available throughout the year but they appear in the stomach of only juvenile pond-smelt in the months of March to June.

10. The forage ratio, defined as a proportion of the percentage of occurrence of an organism in the population to the percentage of its occurrence in the stomach of the fish, was calculated on major food organisms, and both number and weight of the organisms were adopted as the basis of calculation. The values of two kinds of ratio thus obtained well corresponded with each other when the percentage of occurrence were high both in stomach and in plankton, but they conflicted when the same percentages were low. Also the forage ratio seemed to be of limited significance because the ratio ranges actually from zero to infinitive, which hardly explain the fish-food relation in the lake water.

The forage ratios calculated for Bosmina and Cyclops did not fluctuate seasonally corresponding to the occurrence of organisms in the stomach as well as in the water, but those for Leptodora and Diaphanosoma corresponded to such natural fluctuations.

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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ON PLANKTON RESEARCH IN JAPAN WITH AN ANNOTATED BIBLIOGRAPHY

by

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A. ROUTINE PLANKTON RESEARCH METHODS

Although various collecting methods may be employed according to the special purposes pursued by the investigation, it is advisable to standardize the method when the research is made in the line of routine investigation on the distribution of plankton.

For the fishery investigations in Japan, which are carried out by the Regional Fisheries Laboratories in cooperation with the Prefectural Fisheries Experimental Stations, the pattern of plankton nets has been standardized after the design of Dr. Zinziro Nakai. The standard net is 45 cm in caliber and one metre in length. It is made of bolting silk with meshes nearly equivalent to No. 3 Muller-gaze in size (approximately 0.3 mm mesh). The small flow-meter devised by him is attached at the center of the mouth ring. This net is usually employed for a vertical haul from 150 metre depth to the surface at the speed of 1 m/sec. This method was first planned for the investigation of the volumetric distribution of general macroplankton, especially of the quantitative distribution of pelagic eggs and larvae of fishes.

The quantitative estimation of the collected material is made by ascertaining the wet weight of plankton organisms, after removing the surface water by placing them on filter paper.

This method has been adopted in the routine plankton collection adopted in sardine fishery investigations, and this enables the data from various sea areas and collected by different investigators to be compared.

A larger net is certainly more suitable for the collection of the large powerful planktonic animals, e.g. Euphausiids; however, the present equipment in general use perhaps makes it impracticable to employ a net with the mouth larger than about 45 cm diameter. For instance, the hand-sounding machine is still used for the haul of the net in some ships, though the electric sounding machine is more common nowadays.

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For sampling the fish eggs and larvae, the collecting capacity of the above method is sometimes insufficient and in addition to the vertical collection a horizontal tow is carried out with a large fry net, 130 cm in caliber, 4.5 m in length, made of stramin in the upper part and of bolting silk with 0.3 mm mesh in the lower. The fry net is usually towed horizontally for 10 minutes at low speed in the surface water at the side of a vessel at about 2.5 knots. As the sardine eggs are always distributed in the upper layer of the sea, they can be collected by the surface tow by day or night.

In the routine oceanographic investigations in Japan, temperature, salinity, oxygen content and concentration of some nutrient salts in the water are commonly measured at several layers, down to the depth of 1,000 metres or more. Although it is also desirable to collect plankton at these levels, this cannot yet be done satisfactorily.

Phytoplankton may be quantitatively collected with some degree of precision by settling or centrifuging the small amount of water sampled with Nansen or other oceanographic bottles, after estimating the quantity of plankton by the troublesome process of counting the number of plankton under the microscope. The validity of the quantitative estimation by net collection has frequently been criticised, and the net collection is generally said to be inappropriate for quantitative investigation of phytoplankton, but it nevertheless constitutes a convenient and simple method not only for obtaining plentiful material but also for the estimation of the bulk of phytoplankton which can easily be known by settling it in a graduated cylinder.

In the case of zooplankton, the Nansen closing plankton net has been widely used as the most simple and convenient method for sectional vertical collection. The Clarke-Bumpus sampler is recommended for simultaneous horizontal collection at various depths, but the horizontal tow with such an instrument requires so much time that it is not yet employed in routine oceanographic observations. The method must be as simple as possible, because the work has to be done with regularity even in rough weather.

The "Twin plankton net" described and illustrated* here was devised by the writer for net collection of phytoplankton as well as of the smaller zooplankton. The construction and the operation of the apparatus are as follows.

Two small nets are supported by a metal framework 16 cm in diameter and 40 cm in height; one net is made of fine bolting silk and another is of comparatively coarse mesh. Several metal frameworks are prepared, each with two nets. These are successively lowered at intervals for depth of 1,000 m and then raised, so that the second framework will come into contact with the first framework and close the first set of nets when this has been raised to a certain depth, say 800 metres. The nets of the first framework would thus collect the plankton from 1,000 to 800 metres, those of the second framework from 800 to 600 metres etc. Thus, each twin net is hauled for a certain distance through different strata, and the plankton distributed at different strata is sampled by a single haul. Each net may be equipped with a flowmeter if necessary.

It is believed that this simple method is appropriate for routine sampling and is practicable under the present circumstances of the research in the Indo-Pacific Region.

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*Illustration retained in Secretariat

B. AN ANNOTATED BIBLIOGRAPHY ON RECENT PLANKTON RESEARCH IN JAPAN

The research work of Japanese investigators on the marine and fresh-water plankton is here reviewed in respect of papers published since 1940 in order to show the recent advances of plankton researches in Japan. The investigators engaged in this field of study belong with few exceptions, to one of the following organizations: the Government Fisheries Research Laboratories, the Prefectural Fisheries Experimental Stations, the Government Marine Meteorological Observatories, the Universities and the Marine Biological Stations.

The research has been performed in several different fields and the description and bibliography are conveniently arranged under the several items.

(I) PLANKTON RESEARCH IN CONNECTION WITH OCEANOGRAPHIC OBSERVATIONS

The type of research focuses mainly on the distribution of the species or communities in relation to the nature of certain ocean currents and is usually carried in connection with the cruises of oceanographic research vessels. The areas investigated cover comparatively large areas of the seas around Japan, and some investigators have worked in the South Seas and in the Antarctic.

The research was undertaken principally in order to ascertain particular indicator species characteristic of the four great currents around Japan, i.e. the warm current, Kuroshiwo, and the cold current, Oyashiwo, in the Pacific, and the warm current, Tsushima Current, and the cold, or Liman Current, in the Japan Sea. On the other hand, collections made at the marine biological stations made clear the seasonal distribution of plankton, such work having been carried out at Oshoro Bay (west coast of Hokkaido), Volcano Bay (east coast of Hokkaido), Mutsu Bay (Aomori Prof.), and Ise Bay (Mie Pref.).

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(II) PLANKTON RESEARCHES IN CONNECTION WITH LIMNOLOGICAL SURVEYS

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(III) VERTICAL DISTRIBUTION OF PLANKTON AND ITS DIURNAL CHANGES

Observations have been made on the vertical distribution and diurnal migration of plankton in the sea as well as in the lakes. It is of great importance to define the lower limit of vertical migrations of plankton, because the vertical haul of plankton net in ocean cruises must be made from depths beyond this limit. The observations were carried on the high sea, 39°N, 153°E, off Shiretoko (Northeast Hokkaido), at Sagami Bay (Shizuoka Pref.), in Lake Abashiri (Hokkaido) and Lake Shikotsu (Hokkaido).

1. Kikuchi, K., Y. Enokida and H. Tateno, 1942. Seasonal change in the vertical distribution of the plankton in Lake Biwa. Jap. Jour. Limnol., Vol. 12, No. 2, pp. 63-72 (in Japanese).
2. Shimomura, T., 1948. Diurnal change of occurrence of plankton in the ocean, N 39°, E 153°, I. Suisangakkaiho, Vol. 10, No. 52, pp. 14-17 (in Japanese).
3. Tamura, T. and A. Fuji, 1949. Vertical distribution of plankton in Lake Shikotsu of Hokkaido. Jap. Jour. Limnol., Vol. 14, No. 3, pp. 133-140 (in Japanese).
4. Motoda, S. and S. Sato, 1949. A brief observation on the diurnal migration of marine zooplankton off Shiretoko, Hokkaido. Sci. Pap. Hokkaido Fish. Sci. Inst., No. 2, pp. 72-77 (in Japanese).
5. Kokubo, S., 1950. The ecology of certain copepods in Japan Sea and Mutsu Bay. Bull. Jap. Soc. Sci. Fish., Vol. 16, No. 5, pp. 215-220 (in Japanese).
6. Motoda, S. and T. Ishida, 1950. An observation on the diurnal migration of plankton crustaceans at Lake Abashiri, Hokkaido, in summer of 1947. Sci. Rep. Hokkaido Fish Hatchery, Vol. 5,

No. 2, pp. 1-8 (in Japanese).
7. Shimomura, T., 1950. On the time variation of the constitution and quantity of plankton in the ocean. Jour. Oceanogr. Soc. Jap., Vol. 5, No. 2/4, pp. 88-93 (in Japanese).
8. Marumo, R. and Y. Kawarada, 1951. On the diurnal variation of planktological conditions at the center of Sagami Bay (I, III). Oceanogr. Rep. Central Mar. Obs., Vol. 2, No. 1, pp. 33-42, No. 2, pp. 159-162 (in Japanese).
9. Motoda, S. and M. Anraku, 1951. An observation on the vertical distribution of plankton at Ishikari Bay, Hokkaido. Jour. Oceanogr. Soc. Jap., Vol. 6, No. 4, pp. 194-200 (in Japanese).
10. Ishida, T., 1952. Study of Lake Abashiri: Diurnal migration of plankton crustacea at the position of shallow bay. Sci. Rep. Hokkaido Fish. Hatchery, Vol. 7, No. 1/2, pp. 127-131 (in Japanese).
11. Kawarada, Y., 1952. On the daily change of plankton at the inner part of Sagami Bay. Oceanogr. Rep. Central Mar. Obs., Vol. 2, No. 4, pp. 333-336 (in Japanese).
12. Marumo, R., 1952. On one case of the vertical distribution of phytoplankton in the ocean. Oceanogr. Rep., Central Meteo. Obs., Vol. 2, No. 3, pp. 279-281 (in Japanese).
13. Motoda, S. and M. Anraku, 1952. Observations on the plankton of Funka Bay, Hokkaido. I. Vertical distribution of plankton at the mouth of the bay in August, 1950. Bull. Hokkaido Reg. Fish. Res. Lab., No. 5, pp. 17-20 (in Japanese).
14. Motoda, S., 1953. Observations on diurnal migration of plankton crustaceans in Lakes Shikotsu, Hokkaido, and Tsugarujuni, Aomori, and some experiments on photo- and geotropism. Mem. Fac. Fish. Hokkaido Univ., Vol. 1, No. 1, pp. 1-56.

(IV) QUANTITATIVE ESTIMATION OF PLANKTON:

This type of research is particularly concerned with the quantity of plankton in an attempt to estimate productivity and was carried out in certain sea areas and inland waters. The Nakai Regional Fisheries Research Laboratory has commenced the systematic survey on the plankton volume in several bays in Japan. In recent surveys made by the members of the Freshwater Fisheries Research Laboratory, the production in lakes was calculated by measuring the photosynthetic activity of planktonic algae.

1. The National Research Council of Japan, 1931-40. Plankton-Jiho. No. 1-15. Results of quantitative estimation of microplankton as observed by settling method from 10 litres of water at 16 stations on the coast of Japan during the years, 1931-1933 (in Japanese).
2. Motoda, S., 1940. Comparison of the conditions of water in the bay, lagoon and open sea in Palao. Palao Trop. Biol. Sta. Studies, Vol. 2, No. 1, pp. 41-48.
3. -----, 1941. Plankton productivity of Iwayama Bay in Palao, South Seas. Ibid., Vol. 2, No. 2, pp. 219-238.
4. Tokioka, T., 1942a. Systematic studies of the plankton organisms occurring in Iwayama Bay, Palao. I. Introductory notes, with some references to the surface water temperature and the settling volume of plankton in the bay. Ibid., Vol. 2, No. 3, pp. 509-519.
5. -----, 1942b. Plankton volume in Iwayama Bay and in the coastal waters of Palao Islands. Kagakunanyo, Vol. 5, No. 1, pp. 44-55 (in Japanese).
6. Hogetsu, K., Y. Kitazawa, H. Kurasawa and Y. Shiraishi, 1950. The relation between productivity and environmental conditions and also material circulation in lake. Jour. Fish. Res. Inst. (Suisankenkyukaiho), No. 3, pp. 58-82 (in Japanese).

7. Tokioka, T. and I. Yamaji, 1950. Quantitative distribution of plankton in Ago Bay, Studies on the culture bed of pearl oyster, No. 2, pp. 5-18 (in Japanese).
8. Kokubo, S., 1951. Research on the productivity of plankton in Mutsu Bay. Rep. Res. Mutsu Bay Branch, Aomori Fish. Exp. Sta., pp. 37-46 (in Japanese).
9. Naikai Regional Fisheries Research Laboratory, 1951. Report on the research of productivity of various bays in Japan. 123 p. (in Japanese).
10. Hanaoka, T., 1952. On an indicator of production from a water area. Bull. Nakai Reg. Fish. Res. Lab., No. 1, pp. 42-53 (in Japanese).

(V) STOMACH CONTENTS OF PLANKTON-FEEDING FISH:

The observations on the stomach contents are still limited to a few species of fish, i.e. spring herrings, atka-mackerel (Hekke), and young sand eel (Konago) off the west coast of Hokkaido, Alaska pollack (Sukeso) and other fishes caught by trawl around Hokkaido, red salmon and humpback salmon from the Aleutian Island waters and off the east coast of Hokkaido and the Kurile islands. An attempt has been made to find the direct relationship between the existence of abundant food plankton and the shoaling of fish feeding upon it. The food of sei whales in Bonin Island waters was also observed. In the case of freshwater fishes, the stomach contents of Salvelinus malma (Oshorokoma) at Lake Shikaribetsu (Hokkaido), the pond smelt (Wakasagi) at Lake Abashiri (Hokkaido) and carp fry was studied.

1. Motoda, S. and K. Sakai, 1946. Food of spring herring. Jour. Hokkaido Fish. Sci. Inst., Vol. 3, No. 9/10, pp. 155-165 (in Japanese).
2. Nakamura, N., 1947. The feeding habit of carp fry. Bull. Jap. Soc. Sci. Fish., Vol. 13, No. 3, pp. 111-112 (in Japanese).
3. Hada, Y. and M. Tomita, 1949. Plankton and fishes in some lakes of Hokkaido. I. Salvelinus in the lake Shikaribetsu. Seibutu, Vol. 4, No. 1, pp. 21-26 (in Japanese).
4. Ishida, T., 1949. Studies on the feeding habit of pond smelt in Lake Abashiri. Sci. Rep. Hokkaido Fish Hatchery, Vol. 4, No. 2, pp. 47-56 (in Japanese).
5. Motoda, S. and S. Sato, 1949. The food of the spring atka-fish (Pleurogrammus azonus) with its hydrographic bearing. Bull. Jap. Soc. Sci. Fish., Vol. 15, No. 7, pp. 343-353 (in Japanese).
6. Motoda, S. and I. Takeuchi, 1949. Food of spring herring in 1948. Sci. Pap. Hokkaido Fish. Sci. Inst., No. 1, pp. 32-44 (in Japanese).
7. Motoda, S. Y. Tanaka, 1950. Ecological investigations on the young sand-eel around the coast of Hokkaido. II. Feeding habit. Ibid., No. 7, pp. 56-67 (in Japanese).
8. Hokkaido Regional Fisheries Research Laboratory, 1952. Investigation on the resources of bottom fish in eastern trawl ground. No. 1, Hokkaido Region. No. 3, 209 p. (pp. 89-99, stomach content of Alaska pollack) (in Japanese).
9. Motoda, S. and I. Moriyama, 1952. Food composition of bottom fishes and distribution of larger bottom invertebrates. (1950-1951). Rep. Res. Deep Sea Fish. North. Japan Sea, No. 3, pp. 77-90, Otaru, (in Japanese).
10. Nakai, Z., 1952. Notes on the natural food of salmons and the plankton in the Aleutian Island waters. Suisankai, No. 815, pp. 60-65 (in Japanese).
11. Nishimoto, S., M. Tozawa and T. Kawakami, 1953. Food of sei whales (Balaenoptera borealis) caught in the Bonin Island waters. Sci. Rep. Whales Res. Inst., Tokyo, No. 7, pp. 79-85.

12. Takemura, Y. and T. Yamano, 1953. Notes on the food of Pleurogrammus azonus taken from the western coast of Hokkaido. Bull. Jap. Soc. Sci. Fish., Vol. 19, No. 2, pp. 111-117 (in Japanese).
13. Tamura, T. and S. Kawai, 1953. Studies on the natural food of salmons in the offing of the east coast of Hokkaido. Bull. Fac. Fish. Hokkaido Univ., Vol. 3, Special, pp. 50-55 (in Japanese).

(VI) DISCOLOURED WATER CAUSED BY PLANKTON CONCENTRATION:

Discoloured water caused by the concentration of certain kinds of plankton is often met with in the bays and inlets. It is sometimes harmful to the oysters reared there, (including pearl oysters) and clams. Such discoloration of water was reported at Akkeshi Bay (Hokkaido), Omura Bay (Nagasaki Pref.) and Nakanoumi (Shimane Pref.).

1. Hada, Y., 1940. Red water caused by ciliates. Kagaku, Vol. 10, No. 1, pp. 6-7 (in Japanese).
2. Tsujita, T., 1949. Red water caused by silicoflagellates in Ohmura Bay. Rep. Nagasaki Mar. Meteorol. Observ., No. 2, pp. 17-29 (in Japanese).
3. Horii, T. and T. Ito, 1953. Studies on the red water occurring in Nakano-umi in 1951. Shimane Branch of Bunka Nihon Kenkyu, Bunken, Special Publ., Vol. 2, No. 3, pp. 1-26 (in Japanese).

(VII) PHYSIOLOGICAL STUDIES AND CULTURE EXPERIMENT:

Culture experiments, mostly on the diatoms and cladocerans, made clear the effect of environmental factors upon the growth of the organisms. The artificial rearing of planktonic larvae of invertebrates is successful when suitable food organisms are provided. An unarmored dinoflagellata, Monas, is known to be the most suitable food for the larvae of oysters and scallops. Culture methods of such nannoplankton have been greatly developed.

1. Igarashi, H., 1941. Experiment on the effect of calcium on improvement of bog water. Hokkaido Fish. Sci. Inst., 17 p.
2. Matudaira, T., 1942. On inorganic sulphides as a growth promoting ingredient for diatom. Proc. Imp. Acad., Tokyo, Vol. 18, No. 2, pp. 107-116.
3. -----, 1943. On the physiological factors of clover-extract acting upon the growth of Daphnia, and Scenedesmus. Bull. Jap. Soc. Sci. Fish., Vol. 12, No. 1, pp. 1-17 (in Japanese).
4. Nakai, Z., 1942. The chemical composition, Volume, weight and size of the important marine plankton. Jour. Oceanogr. Soc. Japan, Vol. 1, No. 1/2, pp. 45-55 (in Japanese).
5. -----, 1947. Estimation of oil in dopepodae: a method and some results. Bull. Jap. Soc. Sci. Fish., Vol. 13, No. 1, pp. 8-11 (in Japanese).
6. Tsuchiya, Y., 1947. The toxic action of various sulphur compounds upon Daphnia pulex. Ibid., Vol. 13, No. 3, pp. 113-114 (in Japanese).
7. Hoshi, T., 1949a. Studies on physiology and ecology of plankton I Hydrogen ion concentration and oxidation reduction potential in a cladoceran culture. Sci. Rep. Tohoku Univ., 4 Ser., Vol. 18, No. 2, pp. 153-158.
8. -----, 1949b. Studies on physiology and ecology of plankton. II. Oxygen consumption and heart beat rate in developmental stages of Simocephalus vetulus (O.F. Muller). Ibid., Vol. 18, No. 2, pp. 150-161.

9. Matsue, Y., 1949a. Phytoplankton and its oxidisability by permanganate. Bull. Jap. Soc. Sci. Fish., Vol. 15, No. 12, pp. 813-817 (in Japanese).
10. -----, 1949b. Physiological analysis of sea water and phosphate reserve of plankton diatom. Jour. Fish. Res. Inst. (Suisan Kenkyu Kai-ho), No. 2, pp. 29-42 (in Japanese).
11. Aichi Prefectural Fisheries Experimental Station, 1950. Propagation of water flea by utilization of electric heat. 22nd Zenkoku Kosho Kasen Yoshoku Kenkyu Kai Yoroku (Naganoken), pp. 66-69 (in Japanese).
12. Hoshi, T., 1950a. Studies on physiology and ecology of plankton. III. Changes in respiratory quotient during embryonic development of a daphnid, Simocephalus vetulus (O. F. Muller). Sci. Rep. Tohoku Univ., 4 Ser., Vol. 18, No. 3, pp. 316-323.
13. -----, 1950b. Studies on physiology and ecology of plankton. IV. Temperature coefficients and temperature characteristics of the oxygen consumption in Simocephalus vetulus. Ibid., Vol. 18, No. 4, pp. 460-463.
14. -----, 1950c. Studies on physiology and ecology of plankton. V. Fatty substance in development of Simocephalus vetulus, with reference to behavior of yolk granule. Ibid., Vol. 18, No. 4, pp. 464-466.
15. Imai, T., D. Inaba, R. Sato and M. Hatanaka, 1950. On the artificial breeding of Japanese sea-cucumber, Stichopus japonicus Selenka. Bull. Inst. Agr. Res. Tohoku Univ., Vol. 2, No. 2, pp. 269-277 (in Japanese).
16. Kokubo, S., 1950a. Culture method of nannoplankton (Monas sp.) for use in rearing of scallop larvae. Rep. Res. Fish. Resources, Aomori Pref., pp. 172-178 (in Japanese).
17. -----, 1950b. Relation between the culture of nannoplankton (Monas sp. and Heteromita sp.) and pH value of sea water. Ibid., pp. 179-182 (in Japanese).
18. Matsue, Y., 1950. The variation of titratable base in sea water. Jour. Oceanogr. Soc. Jap., Vol. 6, No. 1, pp. 32-37 (in Japanese).
19. Hoshi, T., 1951a. Studies on physiology and ecology of plankton VI. Glycogen in embryonic life of Simocephalus vetulus, with some notes on the energy source of development. Sci. Rep. Tohoku Univ., 4 Ser., Vol. 19, No. 1, pp. 123-132.
20. -----, 1951b. Studies on physiology and ecology of plankton. VII. Hatchability of the summer egg of a daphnid, Simocephalus vetulus, cultured in artificial media. Ibid., Vol. 19, No. 2, pp. 145-151.
21. -----, 1952. Studies on physiology and ecology of plankton. VIII. Behavior of embryo of Simocephalus vetulus stained vitally with rH-indicators under aerobic and anaerobic conditions, with a note on the anaerobic metabolism. Ibid., Vol. 19, No. 3, pp. 221-230.
22. Imamura, H., 1952. Effect of phytohormone on the growth of diatom. Bull. Jap. Soc. Sci. Fish., Vol. 17, No. 10, pp. 289-295.
23. Sato, T., 1948. Relation between the growth of larvae of Japanese oyster and the temperature and specific gravity of the surface water. Jour. Fish. Res. Inst. (Suisenkenkyukaiho), No. 1, pp. 1-21 (in Japanese).
24. Hirano, R., 1953. On the rearings and metamorphoses of four important barnacles in Japan. Jour. Oceanogr. Soc. Japan, Vol. 8, No. 3/4, pp. 139-143 (in Japanese).
25. Hoshi, T., 1953. Studies on physiology and ecology. IX. Changes in the glycogen content during development of the daphnid, Simocephalus vetulus, under aerobic and anaerobic conditions. Sci. Rep. Tohoku Univ., 4 Ser., Vol. 20, No. 1, pp. 6-10.

(VIII) PLANKTON REGULATION IN RESERVOIR:

The increase of microplankton in reservoirs often causes the clogging of the cleaning bed. It is necessary for the management of the reservoir to make routine observations on the fluctuations of plankton, so that appropriate measures may be taken. Observations have been carried on at Murayama and Yamaguchi Reservoirs for Tokyo City, and dilute copper sulphate was used for the destruction of microplankton.

1. Kojima, S., 1949a. Limnological studies on reservoir. IV. Annual change of vertical distribution of plankton at Yamaguchi Reservoir of Tokyo. Suidokyokai-zasshi, No. 175, pp. 23-31 (in Japanese).
2. -----, 1949b. Limnological studies on reservoir. V. Horizontal distribution of plankton in reservoir. Ibid., No. 176, pp. 16-22 (in Japanese).
3. Kojima, T., 1951a. Studies on the treatment of algae by copper sulphate in reservoir. I. Treatment of algae by copper sulphate in circulation period. Ibid., No. 196, pp. 9-12 (in Japanese).
4. -----, 1951b. Studies on the treatment of algae by copper sulphate in reservoir. II. Treatment of algae by copper sulphate in stagnation period. (1). Ibid., No. 204, pp. 25-28 (in Japanese).
5. -----, 1951c. Studies on the treatment of algae by copper sulphate in reservoir. III. Treatment of algae by copper sulphate (2). Ibid., No. 205, pp. 13-17 (in Japanese).
6. -----, 1952a. Studies on the treatment of algae by copper sulphate in reservoir. IV. Treatment of algae by copper sulphate in summer partial circulation period. Ibid., No. 207, pp. 13-16 (in Japanese).
7. -----, 1952b. Studies on the treatment of algae by copper sulphate in reservoir. V. Treatment of algae by copper sulphate in stagnation period. (3). Ibid., No. 208, pp. 6-10.

(IX) COLLECTING METHOD:

Some authors have discussed the reliability of net collection for quantitative studies. On the other hand, vertical collection at certain intervals of distance would be meaningless, when unevenness occurs in the horizontal distribution. This is also a serious problem in research on the distribution of plankton.

New patterns of under-way samplers were invented, one of them being a sort of continuous collector, but these were used only for special purposes.

1. Motoda, S., 1949. Hand-made apparatus of limnological observation. (Quantitative plankton sampler). Keisonihò, No. 48/49, pp. 16-22 (in Japanese).
2. Tamura, T., 1948. The method of collecting the plankton while the boat is in motion. Jour. Fish. Hakodate Coll. Fish., No. 53, pp. 1-4 (in Japanese).
3. Egusa, S., 1949. The seasonal variation of size in phytoplankton and the reliability of net collection. Bull. Jap. Soc. Sci. Fish., Vol. 15, No. 2, pp. 78-82 (in Japanese).
4. Ishida, T., 1951. On quantitative collection and horizontal distribution of plankton crustacea. Sci. Rep. Hokkaido Fish. Hatchery, Vol. 6, No. 1/2, pp. 181-190 (in Japanese).
5. Motoda, S., 1953. New plankton samplers. Bull. Fac. Fish. Hokkaido Univ., Vol. 3, No. 3, pp. 181-186.

(X) MISCELLANEOUS:

There are also numerous papers on plankton dealing with aspects other than those described above. Some authors have reported the existence of a special water layer which reflects sound waves emitted from the ship. This layer detected by echo-sounding was supposed in some cases to the the result of the concentration of plankton population.

1. Kinosita, T. and S. Sibuya, 1941. The diurnal and tidal changes in the number of larvae of Pecten and gastropoda in the surface layer of Lake Saroma. (Preliminary report). Bull. Jap. Soc. Sci. Fish., Vol. 10, No. 1, pp. 43-46 (in Japanese).
2. Mori, S., 1942. Horizontal distribution of the plankton at the south part of Lake Biwa. Jap. Jour. Limnol., Vol. 12, No. 3, pp. 94-100 (in Japanese).
3. Negoro, K., 1942. On the condition of life of Cyanidium cladorium (Tilden) Goitler in the organic acidotrophic inland water in Japan. Jap. Jour. Limnol., Vol. 12, No. 1, pp. 41-49 (in Japanese).
4. Seishi, R., S. Inaba and T. Tomiyama, 1942. On the limnological change unfavorable for the fauna and flora of Sanaruko, Sizuoka Prefecture. Ibid., Vol. 11, No. 3, pp. 137-145 (in Japanese).
5. Ito, Takashi, 1949. On the law of geometrical progression in limnoplankton. Ibid., Vol. 14, No. 3, pp. 127-132 (in Japanese).
6. Suginome, M., 1949. On the plankton contained in the ice of freshwater. Bull. Jap. Soc. Sci. Fish., Vol. 15, No. 5, pp. 216-220 (in Japanese).
7. Ishikawa, M. and Y. Oshima, 1950. On the life history of a mysid crustacean, Neomysis japonica Nakazawa. Ibid., Vol. 16, No. 10, pp. 461-472 (in Japanese).
8. Marumo, R., 1951. On the correlation between plankton volume and transparency in the neighbouring seas of Japan. Jour. Oceanogr. Soc. Jap., Vol. 7, No. 1, pp. 1-5 (in Japanese).
9. Tamura, T., 1951. Observation of the plankton in drift ice. Bull. Fac. Fish. Hokkaido Univ., Vol. 1, No. 3/4, pp. 134-138 (in Japanese
10. Hanaoka, T., 1952a. Study on free-living copepoda nauplius. Bull. Nakai Reg. Fish. Res. Lab., No. 1, pp. 1-36 (in Japanese).
11. -----, 1952b. On nauplius of Oncaea mediterranea and Corycaeus sp. Ibid., No. 1, pp. 37-41 (in Japanese).
12. Hirano, R. and J. Okushi, 1952. Studies on sedentary marine organisms. I. Seasonal variations in the attachment and growth rates of barnacle cyprids in Aburatusbo Bay, near Misaki. Bull. Jap. Soc. Sci. Fish., Vol. 18, No. 11, pp. 639-644 (in Japanese).
13. Koizumi, M., 1952. The annual variation in and correlation between colour of the sea, transparency and plankton volume around the fixed point "Extra". Jour. Oceanogr. Soc. Jap., Vol. 8, No. 2, pp. 79-83 (in Japanese).
14. Kotake, N., 1953. Experimental studies on the propagation of the pearl oyster, Pinctada martensii. I. Seasonal appearance of planktonic larvae stage. Bull. Jap. Soc. Sci. Fish., Vol. 19, No. 3, pp. 145-150 (in Japanese).
15. Owatari, A., K. Furuno and S. Matsumoto, 1953. Plankton detected by fish-finder. Rep. Fishery Section, Nagasaki Pref. Office, No. 6, pp. 1-8 (in Japanese).
16. Saito, I. and S. Mishima, 1953. Studies on detection of plankton by echo-sounder (or fish-finder) and selection of fishing station in a fishing ground. Preliminary report. Detection of D.S.L. by echo-sounder. Bull. Fac. Fish. Hokkaido Univ., Vol. 3, No. 4, pp. 269-272 (in Japanese).
17. Tsujita, T., 1953. A preliminary study on naturally occurring suspended organic matter in waters adjacent to Japan. Jour. Oceanogr. Soc. Jap., Vol. 8, No. 3/4, pp. 113-125 (in Japanese).

18. Wada, S. K., 1953. Notes on the ecology of plankton copepod, Labidocera pavo Giesbrecht. Rec. Oceanogr. Wks. Japan, N.S., Vol. 1, No. 1, pp. 100-102.

(XI) TAXONOMIC STUDIES:

Many papers on the taxonomy on each group of plankton algae and animals have been published, as is shown in the following list. The fine structure of diatom frustules was becoming clear from observations with the electron microscope, which makes precise identification possible. One author adopted the stochastical method in determining the morphological variation of freshwater Calanoid copepods.

(1) Phytoplankton: (including flagellata)

1. Matsue, Y., 1942. Systematic studies of the plankton organisms occurring in Iwayama Bay, Palao. II. List of diatoms occurring in the bay. Palao Trop. Biol. Sta. Studies, Vol. 2, No. 3, pp. 521-525.
2. Yamaguti, H., 1942. The desmids of the bog-lake Daitaku of northern Korea. Jap. Jour. Limnol., Vol. 11, No. 3, pp. 117-129 (in Japanese).
3. Yanagizawa, T., 1943. On the silicoflagellata. Umitosora, Vol. 23, No. 1, pp. 451-469.
4. Fukushima, H. 1949-50. Studies on the freshwater algae under various items, Igakutoseibutsugaku, Vol. 15, No. 4, pp. 223-225, No. 5, pp. 293-295, Vol. 16, No. 2, pp. 105-107, No. 6, pp. 337-339, Vol. 17, No. 3, pp. 176-178 (in Japanese).
5. -----, 1950a. Illustrations of Japanese inland water algae. 18. Diatom, Genus Neidium. Collecting and Breeding (Saishu-to-Shiiku), Vol. 12, No. 7, pp. 297-298 (in Japanese).
6. -----, 1950b. Algal vegetation of Shima Hot-spring. Jour. Jap. Bot., Vol. 25, No. 8, pp. 173-178 (in Japanese).
7. Hirose, H., 1950. Study on the phytoplankton of Lake Abashiri. Bull. Jap. Soc. Sci. Fish., Vol. 16, No. 1, pp. 25-30 (in Japanese).
8. Tokioka, T., 1950a. Illustrations of marine plankton. No. 1, Dinoflagellata. 4 p., 4 pls. Nanki-seibutsu, Vol. 1, No. 3, (mimeogr.) (in Japanese).
9. Tokioka, T., 1950b. Illustration of marine plankton. No. 2, Diatom. Seto Mar. Biol. Lab., Kyoto Univ., 29 p. (in Japanese).
10. Akatsuka, K., 1951. Key and illustrations of plankton (1) Cyanophyceae. Mat. Sci. Fish., Fac. Fish. Pref. Univ. Mie, No. 1, pp. 1-18, pls. 1-3 (in Japanese).
11. -----, 1952. Key and illustration of plankton (2) Dinoflagellata. Ibid., pp. 19-48, pls. 12-34 (in Japanese).
12. Okuno, H., 1951. Electron microscopical study on Antarctic diatoms (1). Jour. Jap. Bot., Vol. 26, No. 10, pp. 305-310 (in Japanese).

(2) Foraminifera

1. Hada, Y., 1943. Foraminifera of Palau Islands (2). Kagakunanyo, Vol. 5, No. 2, pp. 194-214 (in Japanese).

(3) Rotifera

1. Kawakita, S., 1942. The Loricata (Rotatoria) from the Osaka Municipal water works. Jap. Jour. Limnol., Vol. 11, No. 3, pp. 76-84 (in Japanese).
2. Yamamoto, K., 1949-52. Rotifer fauna of Japanese inland waters. (1) - (8). Jap. Jour. Limnol., Vol. 14, No. 2, pp. 91-98; No. 3, pp. 141-145: No. 4, pp. 189-194; Vol. 15, No. 1/2, pp. 42-50; No. 3/4, pp. 81-87; Vol. 16, No. 1, pp. 24-30; No. 2, pp. 68-74 (in Japanese).

(4) Coelenterata

1. Komai, T. and T. Tokioka, 1942. Three remarkable ctenophores from the Japanese Seas. Annot. Zool. Jap., Vol. 21, No. 3, pp. 144-151.
2. Uchida, T., 1947a. Some medusae from the Central Pacific. Jour. Fac. Sci. Hokkaido Univ., Ser. VI, Zool., Vol. 9, No. 3, pp. 297-319.
3. -----, 1947b. Medusae in the vicinity of Shimoda. Ibid., Vol. 9, No. 4, pp. 331-343.

(5) Crustacea

1. Kikuchi, K., 1940. Freshwater copepoda of Manchuokou. Rep. Limnol. Surv. Manchuria and Kwantung Prov., pp. 281-300 (in Japanese).
2. Mori, T., 1940. Two new copepods from Japanese waters. Zool. Mag. (Jap.), Vol. 52, No. 8, pp. 328-330.
3. Ueno, M., 1940a. Freshwater amphipoda of Manchuokou. Rep. Limnol. Surv. Manchuria and Kwantung Prov., pp. 311-322 (in Japanese).
4. -----, 1940b. Freshwater cladocera of Manchuokou. Ibid., pp. 323-367 (in Japanese).
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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

CONSEIL INDO-PACIFIQUE DES PÊCHES

CONSEJO DEL INDO-PACIFICO PARA PESQUERIAS

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5th Meeting, Bangkok, Thailand
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IPFC/C54/SYM II-1

SOME IMPORTANT SOCIO-ECONOMIC PROBLEMS OF THE FISHERY INDUSTRIES OF JAPAN

by

N. Oka[x], I. Konuma[x], K. Yamamoto[x] and M. Abe[x]

1. INTRODUCTION

With the development of fisheries, (1) the maintenance or increase of production of fish and the conservation of aquatic resources, (2) the division of fisheries profits and (3) the improvement of marketing of catches have become some of the most important problems of the fishery industries of Japan. In the search for solutions to these problems, efforts are being concentrated upon the appropriate utilization of fishing grounds, the improved organization of fish markets and the establishment of a fisheries finance system.

Even though the system of fishing rights and the administration of fishing grounds had undergone reorganization from time to time, the fisheries system after World War II still retained vestiges of irrational and feudalistic practices. To cope with this situation, fisheries reform has been carried out recently on an unprecedented scale, involving several new lines of action. The main points involved in this reform are here recorded by I. Konuma, Secretary of the Japanese Fisheries Agency.

The functions of fish markets differ between wholesale markets in producing places and those in consuming places, and the characteristics vary according to local circumstances. The section of this paper prepared by K. Yamamoto, Secretary, Japanese Fisheries Agency, includes a brief history of the Japanese fish markets and their organization, and an outline of the Tokyo Central Wholesale Market, Tsukiji.

Lastly, the section by M. Abe, Secretary, Japanese Fisheries Agency, gives information on the form and function of fisheries finance, which is essential to the maintenance and improvement of fisheries production.

It is a significant fact that the livelihood of a large proportion of the total population of Japan is dependent upon the fisheries and the major source of animal protein in Japan derives from the sea. It is believed that a better understanding of the present economic status of the fisheries industries which have only a scanty accumulation of capital, will be obtained from the present study of the papers.

(N.Oka)

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2. FISHERIES REFORM IN JAPAN

After World War II, the Japanese Government took up Fisheries Reform together with Agricultural Land Reform under the guidance of the Headquarters of the Occupation Army. The Fisheries Reform was brought into operation a little later than the Agricultural Land Reform, by the passage of suitable legislation through the Diet in 1949 and was completely carried out during 1950 through 1951.

The whole aspect is as follows:

a) Object of the Reform

The object of this Reform is to establish a new system of fisheries administration on the basis that the promotion of fish production and the rehabilitation of the fisheries should be carried out as an important link in the chain of an overall democratization of Japan and reconstruction of her economy.

In the process of this Reform all traditional fishing rights or fishing ground relations in coastal and inland waters established under the Fisheries Law of 1910 are to be revoked, and are to be replaced by new fishing rights or grounds established through the recommendations of democratic adjustment organizations whose membership consists chiefly of working fisheries operators and employees.

b) Steps of the Reform

The new Fisheries Law and its related laws are conducive to these objects and lay down procedures for the enforcement of the Reform. Under these laws, in the first place, all the traditional fishing rights which existed at the time the legislation was enacted were revoked within a fixed period not exceeding two years in maritime areas, and new fishing rights were established on democratic principles.

For the old fishing rights thus cancelled, the Government made compensation amounting to 17 thousand million yen in government bonds redeemable in 30 years. The fees to be collected in respect of the new fishing rights & licences have been earmarked as a contribution towards this compensation. It is worthy of note that this compensation has been reduced through so-called "capitalization of securities" so as to expedite the progress of the Reform. In this important respect the Fisheries Reform differs from the Agricultural Land Reform.

Toward the end of 1952, however, this system of payment of nominal annual fees met with a strong opposition from the fishermen. Consequently, it was repealed in 1953 by amendments to the Fisheries Law passed by the Diet on August 6, 1953.

c) New Fishing Rights

The new rights are basically different from the old and traditional ones. Most of the owners of the old rights were fisheries associations or privileged individuals who might freely lease or sell their rights, while working fishermen were not able to operate the fisheries without paying rent to the rightful owners.

The newly established fishing rights, however, constitute a sort of business right or license. Though regarded as real rights with exclusive ownership, they are not considered to constitute

the ownership of property, and consequently any new rights cannot be leased nor sold by the owners. In these conditions, new rights can be granted only to those who actually operate fisheries themselves. Thus, the idea of the absentee landlord exploiting the rent of fishing grounds or rights from working fishermen on the basis of lease contracts has been rejected, and a freer management of the fisheries has been developed. This is one of the most important points of the Reform.

The major types of the new fishing rights are fixed-net, demarcated and common fishing rights, together with common piscary rights established on the other three rights. The duration of the grant has been fixed for each type of these rights. In the case of the demarcated fishery right, for an example, its term is for five years, subject to renewal. This system has been established in order to prevent the permanent ownership of fishing rights and to secure the effective management of fisheries by the fishermen.

d) Procedures for Granting of Fishing Rights

In granting fishing rights, prefectural governors determine the type of fishery, location and area of fishing grounds, fishing season, etc., after hearing the opinion of the Sea-area Fisheries Adjustment Commission concerned, and grants are made to applicants according to eligibility and priority as prescribed in the Law, and with referring to the opinions of fishermen at a public hearing.

Eligibility and priority vary according to the type of fishery and have been so devised that the democratization and productivity of the fisheries may be developed freely without being obstructed by domination from out-moded vested interests.

c) Sea-area Fisheries Adjustment Commission

In order to secure an overall rational utilization of fishing grounds and at the same time to adjust possible disputes among fishermen, a democratic organization invested with full powers called the Sea-area Fisheries Adjustment Commission has been set up in each prescribed sea-area throughout the country.

In the demarcation of the fishing grounds, the granting of fishing rights and other important matters, the Prefectural Governor should refer to the opinion of the Commission.

There are now 179 prescribed sea-areas, each of which has a fisheries adjustment commission comprised of seven persons elected from among fishermen, two persons appointed by the Governor from among persons of learning and experience and one person appointed by the Governor from among representatives of the public interests in the sea-area. With regard to inland waters, there has been established over each prefecture one Inland Waters Fishing Ground Administration Commission having almost identical organization, functions and powers to those of the Sea-area Fisheries Adjustment Commission. These two Commissions play an important role in the carrying out of the Fisheries Reform since they allow the fishermen's opinion to be heard.

f) Progress of Enforcement

The progress of the Reform may be summarized as follows:

Date	Important Items	Remarks
Jan. 1947	1st draft of new Fisheries Law discussed	
June 1947	2nd draft of new Fisheries Law discussed	
Aug. 1948	3rd draft of new Fisheries Law discussed	
Dec. 2, 1948	Temporary Measure Law for Fishery Rights and Others enforced	
Dec. 15, 1948	Fisheries Cooperative Association Law enforced	
Jan. 1949	4th draft of new Fisheries Law discussed	
May 1949	Bill for new Fisheries Law submitted to the Diet	Discussion was continued during 5th and 6th sessions of the Diet
Dec. 15, 1949	Fisheries Law and Enforcement Law concerning Fisheries Law promulgated	
Mar. 14, 1950	Fisheries Law and Enforcement Law concerning Fisheries Law enforced	
May 13, 1950	Determination and public notification of prescribed sea-areas	49 in Hokkaido and 130 in Honshu and others.
June 13, 1950	Central Fisheries Adjustment Council established	15 members: 10 representatives of fisheries operators and employees and 5 persons of learning and experience
July 8, 1950	Seto Inland Sea Fisheries Adjustment Office established	
Aug. 13, 1950	Election of Sea-area Fisheries Adjustment Commission	
Sept. 15, 1950	Fishery Rights Compensation Committee established	
Sept. 15, 1950	Inland Waters Fishing Ground Administration Committee established	

b. Spawn-Predatory Plankton (SP Plankton): Those organisms which prey on eggs and larvae of economic fishes or are harmful to their development are included in this category. Since the growth and distribution of plankton fluctuate to a considerable extent depending on the environment, the relationship between SP Plankton and its potential victims cannot be neglected when considering the economic marine resources. Plankton which consumes the larger, adult forms, is discussed under Catch-plundering Plankton (CP Plankton).

D. Symbiotic Plankton (SB Plankton)

Little attention has been paid to that type of plankton which appears to be in a state of symbiosis with economic fishes. Nevertheless, young fish of some species are from time to time reported to associate with jellyfish. The author was able to observe "kita yurei kurage" (north ghost medusa), *Cyanea capillata* Eschscholtz being followed by a host of the young of "komai" or wachna cod, *Eleginus novaga* (Kolreuter). The observation led me to the assumption that the latter fish would escape from its enemies' attack under the shelter of the former, while the medusa could easily feed on the latter's enemies approaching them. However, a question as to whether or not animals in these cases are really in symbiosis with each other, still remains to be proved. They are not, therefore, at present considered important to the commercial fisheries.

3. FISHING-RELATED PLANKTON (FR PLANKTON)

Information on standing crops of plankton in an area often facilitates the detection of fish shoals and hence the location of profitable fishing grounds. Little attention has, however, been given to the relationships existing between plankton and various other factors involved in fishing such as gear, methods, efficiency of operation and size of catch. We will deal with these problems under separate categories.

A. Fish-Indicator Plankton (FIND Plankton)

As is mentioned in a previous paragraph, the majority of plankton serves directly or indirectly as food for economic marine life. Although some of the species are harmful and repellent to fishes, it is probable that the occurrence of plankton is almost always associated in some way with the presence of economic fishes. For this reason, the distribution of plankton and its quantitative, qualitative, seasonal, diurnal, and geographical occurrence, has much to do with the distribution, migration and the detection of the existence of marine animals.

a. Direct-Food Plankton (DF Plankton): The relationship between distribution of aquatic animals and the food on which they depend can be made use of in selecting a fishing ground. Certain types of commercial fisheries are making use of this technique.

b. Indirect-Food Plankton (IDF Plankton): An animal in a higher order may depend indirectly on the presence of other, lower organisms even though they do not enter directly into its food. Plankton in such an association with economic fish may be used as an indirect indicator of fishable waters.

c. Coinciding-with-Fish Plankton (CF Plankton): There are some plankton and economic fishes which occur in a common environment, although there is apparently not a food relationship. In such cases, proper judgement on the periodical occurrence, amount and geographical distribution of fish may sometimes be determined from the presence of this type of plankton.

3. FISH MARKETING IN JAPAN

The organization and management of Japanese fish markets are at present based on the principle of capitalism. The fishery industries exist basically for the purpose of selling goods and specialized activities must be developed from before production right through to consumption. These activities must be supported by the capitalization of distribution especially in cities and large towns in which the sale of such perishable commodities must be organized to deal systematically with large quantities of merchandise.

In the process of channeling fishery products from the producer to the consumer, they must necessarily pass through two areas, i.e., where they are produced or landed, and where they are consumed. The markets in these areas may be classified accordingly as:

a) markets in producing areas and
b) markets in consuming areas.

The former are set up in areas where large amounts of fish are landed by producers, while the latter exist in areas which contain a great mass of consumers. Even though an area or place may have markets of the two categories at the same time, the predominancy of either of the two functions will decide the character of the market.

The regular circulation of products through these two markets is as follows:

Fishermen → Wholesalers → brokers → wholesalers → brokers →
(A) (B)
retailers → consumers

A. Organization and Management of Markets in Consuming Areas

a) History of Marketing Organizations

The organization and management of markets in consuming areas are now regulated by the Central Wholesale Market Law. There was, however, no legislation for this purpose thirty years ago.

Taking the Tokyo Central Market as an example, before the establishment of the present market there was a fish market at Nihonbashi, Tokyo. The market at that time, with imperfect facilities and unsound management, found it hard to maintain itself. Especially in the organization of the market, with an excess of wholesalers split into several factions, it failed to make fair and proper transactions in the collection, distribution and appraisal of products, which gave rise to futile competition among the wholesalers and was at the same time disadvantageous to both the producer and consumer.

As a counter-measure to such unsatisfactory conditions in Tokyo and some other cities, the Central Wholesale Market Law was enacted in March, 1923. Under this Law, forty-one central wholesale markets were designated throughout the country, and the following eleven cities now have central markets:

Kyoto (established in 1927), Kochi (1930), Yokohama (1931), Osaka (1931), Kobe (1932), Tokyo (1935), Nagoya (1949), Hiroshima, Kure, Kagoshima and Sasebo.

The main objects of the Law may be summarized as follows:

(1) Futile and irrational competition is checked in the sale of fish, which is to a large extent caught by modernized fisheries with appreciable capital investment;

(2) Satisfactory sanitary arrangements and facilities are provided for the handling of fish; and

(3) The market is established by public bodies which are independent of the producer and the consumer.

However, under the controlled economy during and after the war, involving the enforcement of the Price Control Ordinance and related orders, the price and distribution of fresh fish and shellfish were put under strict national control in March, 1940, and the brokerage system in the market was abolished in October, 1941. Consequently, fish wholesale markets in Japan ceased to carry on their proper functions for ten years until the overall control on fishery products was removed in April, 1950.

(a) Present Conditions of Markets

A central wholesale market consists of a management, wholesalers, brokers and retailers. Transactions in the market are made between the wholesaler and the broker, and between the broker and the retailer. In the former case, fish is sold by the wholesaler, as consignee, to the broker by auction. In this transaction, 6% commission is charged by the wholesaler. In the latter case, however, private transactions are made on a personal basis. The broker divides up the auctioned articles and delivers them to the retailer, who in turn carries them to the consumer.

The Tokyo Central Market was established in 1935 by the Metropolitan Government, and it has now 10 wholesale firms, 1,700 brokers and 7,000 retailers. Through the transactions between the wholesaler and the broker, reasonable competitive prices are established by species of fish, and the inter-relationship of demand and supply is automatically adjusted. The Central Market in Japan, in this way, carries on important economic functions, such as the collection, distribution and appraisal of fishery products, including the encouragement of their consumption on the one hand and expansion of their production, on the other.

B. Organization and Management of Markets in Producing Areas

Fish markets in producing areas vary in scale from very small and temporary markets in fishing villages to those of large size in big towns where voluminous landings are made throughout the year, thus representing a cross-section of the economic structure of the fisheries of Japan. The size of these markets depends upon their location and transport facilities as well as upon the development of fisheries production in their vicinities.

Japan has now more than 4,000 fish markets throughout the country, mostly established by public bodies or fishermen's cooperatives.

The management of these markets is usually entrusted to wholesalers. In the large markets in producing areas, the great majority of the wholesalers consists of firms, including a few fishermen's cooperatives, while fishermen's cooperatives predominate

in the small market. In either case, the wholesaler in the market of a consuming area is functioning for the benefit of producers.

The fish market in a producing area is organized by wholesalers and brokers. Fisheries products are here sold at auction by the wholesaler to the broker or bid for on behalf of the producers. The products thus purchased by the broker are transported to a wholesaler in a consuming place for his own account. The market price in a producing area is established on the basis of such operations. The fishermen as the producers are very sensitive to the price and are naturally very anxious to ship their products to the most favourable markets.

C. Forms of Circulation of Fishery Products

The relations between the market in a producing area and that in a consuming area may be classified into two types. One is the relationship between the big market in a large producing area and that in an important consuming area, which constitutes a major part of the whole circulation of fishery products in Japan. The other is the relation between the market in a small producing area and that in a farm village.

Among the markets in consuming areas, those in the Kansai and Kanto districts occupy the premier position in the east and the west of the country. The Kansai market, including the markets in Kyoto, Osaka, Kobe and other big cities, is connected directly with the rich producing places in the south-western districts of Japan such as Yamaguchi, Fukuoka, Nagasaki and other prefectures, while the Kanto market, including those in Tokyo and Yokohama and other cities, is supplied chiefly from Hokkaido and the Tohoku district. Consequently, a regular route of circulation of products has been established between the large-scale markets in important producing and consuming areas.

As to the market in a farm village, however, with its weak and scattered consuming power and with its small-scale market, the chief supply of sea-foods for the villagers is secured by small local producers or through the market of a big consuming city or town in its vicinity, which forms a localized route of distribution for small consuming areas.

The consumption of animal protein including fishery products in farm villages of Japan amounts to only a half of that in cities and towns. In view of the health condition of villagers it is regarded as essential to solve the problem of supplying them with more fish at low prices and suited to their taste. Increased productivity of fish in the fishing villages, therefore, is not only very important for stabilizing the management of small coastal fisheries, but it is also a short cut to ensuring a reasonable supply of fish to farm villages. Measures are being taken by the Government to give financial aid for the construction of cold storages as well as fishing ports. Moreover, large markets in big consuming areas, such as the Tokyo Central Market, are now developing a strong tendency to re-ship to farm village markets.

(K.Yamamoto)

4. FORM AND FUNCTION OF FISHERIES FINANCE IN JAPAN

The form and function of finances vary according to the types of the economic system prevailing in different countries and to the stages of their development. It is also true that the economic system is greatly influenced by the function of finance.

The scale of fisheries finance in Japan has undergone

several changes with the progressive stages of development of her fisheries. Until the last years of the 19th century when small-scale fisheries were operated chiefly in coastal waters, the scale of fisheries financing was comparatively small and necessary operational expenses of fishermen were provided through the aid of their relatives and friends or mutual financing associations in addition to their own funds. It can be said, therefore, that the financial problem did not in those days occupy any important position in the fisheries of Japan.

Since the beginning of the 20th century, however, with the development of large nets and other improved gear together with the mechanization of fishing boats and the construction of large and modern type vessels, the small coastal fisheries of former days developed into the larger type net fisheries and the off-shore fisheries. This made it indispensable to obtain a large supply of expensive capital materials. Such trends invited a saturation of monetary economy in our fisheries and required the investment of large amounts of money.

The financing of the fisheries at that time, however, was generally carried on with commercial capital provided by wholesalers or brokers of fish and fertilizers. Consequently, these brokers came to have a predominant power over the fishermen, who were obliged to borrow large sums of money in advance before engaging in fishing operations. Under this "advance loan" system, all the fishermen's catch was cornered and sold by the brokers and the floating debts of the fishermen arbitrarily amortized by the lenders from their fishing income. As might be expected, these practices resulted in the fishermen being deprived of the reasonable profits of their fishing operations, and this resulted in the prevention of a sound development of the Japanese fisheries.

A marked increase in the number of fishermen and the progressive demand for fisheries finance around 1910 caused the Government to enforce a financing system for fisheries on the security of fishing rights owned by fishermen's associations and on that of fishing boats and other property of the fishermen. This was the first step towards the evolution of the modern financing system from the former one dominated by brokers' capital. Such financial aid to the fisheries was made through low-interest, long-term loans from special banks such as the Hypothec Bank of Japan, the Agricultural and Industrial Bank and the Hokkaido Colonial Bank, as well as from the Post Office Insurance Bureau of the Government.

In those days, however, ordinary banks such as city or local banks, excluding those specially connected with fisheries, were not included to come into business relations with fishermen, who generally had only insignificant security and whose activities were usually exposed to much danger and risk.

In 1930 and after, Japan was struck by a severe and widespread financial panic, in which the fisheries operators were also involved. In order to cope with the panic, most fishermen courageously undertook counter-measures for stabilizing the price of their catch as well as for exclusion of unlawful control over their livelihood by merchants. By those measures, the economic functions of fishermen's associations, largely composed of small and medium fishermen, were greatly strengthened through the improved joint marketing of their products and enlarged and well-managed credit facilities. This credit function of the associations was further

improved by their joining, through prefectural fisheries federations, the Central Bank for Industrial Guilds, a special banking institution providing funds for agriculture and forestry and being the highest financing organ which has agricultural and forestal associations as its subordinate organs.

With the improvement in fishing techniques, the enlargement and improved design of fishing boats, and in later years, the extension of fishing grounds to high seas, the scale of fisheries management was gradually expanded, with the result that the instability of fisheries production was eventually overcome.

Such expansion of the fisheries management, involving the capitalization of the fisheries, naturally gave the fishing industry an improved credit standing which in turn made it possible for fishermen to obtain loans from city or local banks like other industries.

Thus, the progress of lending operations proceeded from (1) individuals, through (2) mutual financing associations, (3) wholesalers, (4) special banks, (5) cooperatives to (6) ordinary banks.

Although fisheries finance is now largely operated through ordinary banks, this does not mean that all financial aids from cooperatives, wholesalers or brokers, or other institutions have become unnecessary. The large-scale fisheries are still numerically far inferior to the small-scale operators, who still find difficulty in obtaining loans from banks and there is still a great need for financial aid from individuals and mutual financing associations, while financing through cooperatives still plays an important role.

The reasons why modern financing methods are difficult to adopt in fishing industry may be summarized as follows:

i) The fishing industry is more directly influenced by weather conditions and the production is far more risky than is the case in other industries;

ii) Fisheries products are of a highly perishable nature;

iii) The diversity of fishing seasons and the migrations of fish make it difficult to predict the outcome and therefore militate against the obtaining of loans;

iv) The personal and mortage credit standing in the fishing industry is rather low because of general instability and fluctuation of the enterprise.

In order to cope with such weak points in fisheries finance, the Government of Japan is making efforts to facilitate financial assistance by establishing the Financial Bank for Agriculture, Forestry and Fisheries which is a special organ for financing fisheries and other basic industries by means of long-term, low-interest loans from national funds.

In addition to this, the Law for Insuring Small and Medium Fisheries Finance was enacted in 1953. Under this Law, the funds invested by the Government, local public bodies and fishermen are operated in a manner which will insure the repayment of fishermen's debts to ordinary banks. This system is expected to further smooth the way for the fishing industry to obtain financial aid from ordinary banks.

In conclusion, it must be noted again as mentioned at the outset, that the form and function of national finance make a special contribution to the economic structure of each country.

(M.Abe)

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PROBLEMS OF FISH MARKETING IN THE STATE OF ORISSA

by

G.N. Mitra*

A survey has been made over the last few years of the problems relating to fish marketing in the State of Orissa. The problems vary according to the type of industry and can be described under the following groups.

MARKETING OF MARINE FISH

The State of Orissa has a coast line of approximately 250 miles, of which 90 miles consist of estuaries having no marine fisheries; fishing villages are scattered along the remaining coast line, where seasonal fishing takes place in catamarans and "mango" plank boats. The time spent at sea depends on the weather, tide and the amount of catch made by the fishermen in a particular time. The catch is brought to the shore and disposed of to the waiting retailers who purchase it on a cash and carry basis, thereby freeing the fishermen from further marketing problems. There is a very large number of such merchants who compete with each other, thus ensuring a more or less equitable market rate to the producer. In some cases the richer merchants collect the fish at local market rates for export in ice to distant places. The benefit of the remunerative export business goes entirely to the purchaser, who assumes the risks involved in the fluctuations in the market rates, spoilage etc. The number of boats and nets in each centre is limited and is confined to a few owners.

There is a system of sharing the catch whereby one share is set apart for the boat owner, one share for the net owner and the balance is distributed among the fishermen. If the boat owner and net owner are also fishermen they thus get the corresponding additional shares.

The boats and nets are purchased through credit from the local moneylender at a fairly high rate of interest which ultimately accounts for the poor share of last retail price received by the fishermen.

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Since the fishermen are not experienced in financial matters, they are not considered to be a sound risk by Banks and Co-operatives, as a result of which the fisherman is largely dependent on the village moneylender. As the fishing is seasonal, the fishermen must depend on further cash loans from the moneylender in the off season which is repaid at an interest varying between 19% to 24% or even higher.

Apart from the quantity exported in ice, the rest of the fish is taken in head loads to the villages and sold there at competitive rates. If there is a heavy catch a portion of the fish is dried and sold to wholesale merchants dealing in this commodity, who in turn carry it to village markets and sell it through retailers. It will thus be seen that marine fish marketing gives a living to a large number of men and women, none of whom is prosperous (except the largest merchants); a few of them resort to agriculture to supplement their income.

The fishing villages are mostly located at places without any communication facilities, and during the season when the boats are continuously engaged in fishing, it is not possible for them to secure their daily needs of yarn, rice etc., except through the local dealer, who usually charges them high prices. If there is scarcity of yarn, the bulk of it goes to the weavers, from whom the fishermen can only get a meagre quota through unauthorized channels. Experiments have been conducted in organizing the fishermen into Co-operatives with the single object of obtaining yarn and other commodities. This was given priority over joint marketing because it was felt that the fishermen must be accustomed to the co-operative spirit before further significant steps could be taken. The fishermen, while anxious to satisfy such incidental needs at reasonable prices, do not appear to welcome any measure directed towards getting them out of the clutches of the local moneylenders and sooner or later they return to him, possibly because the moneylender is in more constant touch with the fishermen than the social or Government worker. It has also to be kept in mind that any dislocation of the existing arrangement will deprive a large number of persons of their livelihood, which might give rise to a serious problem in a country like India, unless some alternative occupations were found for the middlemen.

MARKETING OF ESTUARINE FISH

The best developed estuarine fishing ground in the State is the Chilka Lake with an area of some 300-400 square miles. Here carrier agents operate in the lake and purchase fish from the actual fishermen. The fish is taken to assembly grounds and is sold to exporting merchants, who thus collect a large amount of fish from various centres and try to get better prices by sending it in ice to distant places. In spite of inadequate refrigeration facilities the merchant usually earns a good profit and here three distinct economic strata are noticeable. The fisherman who operates inside the lake is the poorest, and in spite of any increase in the price of fish he continues to eke out a living. The carrier agent is slightly more prosperous as he maintains a number of boats which collect the fish from various centres. The exporting merchant is usually very prosperous and many of them have their own wholesale auction depots where they sell their own collections, thus earning profits at both ends. Co-operative marketing can be applied to this field and it will not involve an unemployment problem since the prosperous merchants have enough capital to take into other businesses. The State Fisheries commenced experiments in 1949-50 to develop co-operative marketing and the progress has been remarkable. The number of societies and the volume of business transacted with approximate profits earned can be seen from the following table, year by year. Co-operative

marketing in this case has simply eliminated the exploiting merchants, leaving carrier agents and the auctioneers undisturbed for the present.

Table.

No. of marketing societies.	Volume of business.	Year of business.	Approximate profits earned.
18	26 lakh	1949-50	184,839
20	30 lakh	1950-51	87,034
21	32 lakh	1951-52	96,868

It was decided not to hasten the process because even inside the Co-operatives there are many who take advantage of the lack of education among the members. It is, however, the policy gradually to eliminate or regulate all middlemen operating between the producer and consumer. Villagers who have taken to co-operative marketing have accumulated reserve capital and part of this has been utilised for communal places of meeting, worship or tanks. With the first stage achieved, attention is now being diverted to technical improvement and the societies are now proposing to operate cold storage and carrier launches.

There are, besides the Chilka Lake, two other important estuaries in the State, but it has been possible to arrange a transport service in respect of only one of them. In such areas the producer is completely at the mercy of the salt merchants who purchase and cure fish. The price paid is naturally very low, and transport and refrigeration are the major factors to improve marketing conditions.

MARKETING OF INLAND FISH

The State has a large number of inland fisheries, ranging from small ponds to the reservoirs and rivers. This industry is essentially a cottage industry in that every village has a few fishermen who engage in fishing and in some cases fish rearing. The catches are sold from door to door or brought to the nearest urban area. The fisherman is often assisted in his trade by the members of his family, but there are a few middlemen. These are usually persons owning or leasing the fishing rights, since the fishermen are unable to raise the deposit necessary for the lease. He is therefore compelled to fish on the terms dictated by the owner of these rights. The solution of this problem is a question of land reform. Attempts have, in fact, been made to place certain areas belonging to the State directly at the disposal of fishermen's Co-operatives with satisfactory results. In such cases, the fishermen get the benefit of the whole catch less a reasonable amount to amortize the lease value, and the marketing is done on a family basis.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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INDO-PACIFIC FISHERIES COUNCIL

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A NOTE ON MARKETING AND PRESERVATION OF FISH IN SAURASHTRA

by

K.R. Srivatsa *

1. IMPORTANCE OF THE FISHERIES

The coastal fisheries of Saurashtra from Malia to Sultanpur yielded 856,000 maunds** of fish during 1950-51 and 955,000 maunds during 1951-52. The landings of different types of fishes along with the regions in 1951-52 are indicated below:

Table I

Fisheries.	Zone	Catches in Mds.	Percentage
1. Bombay Duck (Harpodon)	Jafarabad to Nawabundor	620,054	64%
2. Perches, Sea breams, Sharks, Rays, etc.	Throughout	140,673	14.7%
3. Stromateus	Veraval, Mangrol, Porbunder, Jamnagar	50,543	5.3%
4. Sciaena and Polynemus.	Halar, Veraval	65,446	6.9%
5. Prawns and Coilia, Tri chiunus etc.	Halar, Veraval	46,848 21,828	4.9% 2.3%
6. Mullets etc	Halar, South West	9,510	1.0%

The catches of the Japanese trawler, "Taiyo Maru", from December, 1951, to March, 1952, amounting to 22,500 maunds and valued at 230,000 rupees, are included in the above figures. Most of the other catches were made within 7 to 8 miles from the shore.

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** One maund = 40 lbs.

The total landings of 955,000 maunds were sold for Rs. 55 lakhs.

2. DISTRIBUTION

Only 7 to 8% of the population of the State of Saurashtra are fish eaters. Hence, only about 5% of the catch can be consumed locally, the rest being exported. The fishing industry in Saurashtra is therefore intimately linked with export markets and any increase in fish production by more effective exploitation of the seas and productive inland waters is always likely to give rise to a glut in the local sales centres, unless marketing facilities are considerably improved, and this in turn will adversely affect the efforts to develop and improve the fisheries.

(i) Local Markets

In the important cities of Saurashtra, such as Jamnagar, Porbunder, Veraval and Rajkot, fish markets are not kept in sanitary condition. The Porbunder market is the largest and handles about 3,800 maunds of fish per year. The Veraval market is situated nearer to the landing place but it is rather small. In places like Jodiya, Salaya, Malia, Nawabunder, Mangrol, etc. there are no regular markets at all.

(ii) Outside Markets

As marketing of fish in Saurashtra depends mainly on export to places like Ahmedabad, Agra, Ajmer, Surat, Billimora, Baroda, Navsari and Bombay, primary attention has to be paid to the improvement of existing facilities for such trade.

The export trade of fish was and in many places still is in the hands of petty fish mongers who buy the fish from landing places at rates which are fixed every season, or annually. The local rates for 1950-51 and 1951-52 are given in Appendix 1. Before the reorganisation of the Fisheries Department and establishment of Co-operative Societies, these petty merchants used to bind the fishermen to the established low prices by advancing them loans. This practice existed until 1950-51, but during 1951-52 a system was adopted of fixing the prices by a Committee of two representatives of fishermen, two representatives of traders and the District Fisheries Officer. The benefit to the fishermen was obvious and immediate. The wholesale price per maund of assorted fish rose from Rs.4-7-3 to Rs. 5-12-3 per maund or from Rs.0-1-10 to Rs.0-2-4 per lb., mainly because of co-operative marketing. The above price structure appears to be low, but in fact this was the price for Harpodon which amounted to 65% of the fishery. Prime fishes like "Ghol" (Sciaena) and "Dara" (Polynemus) were sold at Rs.0-3-3 per lb. wholesale, Pomfrets at Rs.0-7-0 (average in Halar and Veraval) and "Surmai" (Cybium) and "Palla" (Hilsa) etc. at Rs.0-4-0. The price structure cannot be further increased unless faster and cheaper transport methods are made available.

Marketing has been taken up in Veraval by the fishermen's Co-operative Societies known as the Mahasagar Sahakari Mandal. Fish to the value of 130,000 rupees was marketed in 4 months of 1951. Tenders were invited for the purchase of the out-put of the members of the Veraval Society; the fish was delivered at the landing places and sale proceeds immediately collected. The fishermen are thus able to obtain 10% more of the sale price than was the case in 1950-51. The export trade of fish is effected by sea, rail and land routes. About 89% of the exported fish was sent by sea, out of which 81% was sub-dried Bombay Duck and Coilia, 9% cured fish like Jewfish, Indian Salmon, Perches, Mullets, Hilsa etc. and about 9½% iced and chilled fish, like

Pomfrets, Hilsa, Sea breams, Jewfish and Indian Salmon. Sun-dried fish, cured fish and manure were exported to Gujarat. Apart from two power vessels carrying iced fish from Jamnagar catches from Veraval and Mangrol were taken to Bombay in country craft for which journey even carrier launches take about 28 to 30 hours. In view of the better prices prevailing in Bombay for iced and chilled fish and since transportation is cheaper by sea than by rail, it is necessary to encourage transport by sea by providing fast carrier launches with insulated storage and cheaper ice and cold storage facilities at landing and receiving centres. The cost for transporting one maund of fish from Veraval to Bombay is as follows:

VERAVAL TO BOMBAY	PER MAUND OF 40 LBS.
Launch hire per trip.	Rs.2-1-0
Ice charges.	Rs.1-0-0
Landing charges at Veraval and Bombay.	Rs.0-8-0
	Rs.3-9-0

(Based on a hired launch with a 4½-ton fish hold).

If greater sea transport facilities are afforded, the difference between the Bombay and Saurashtra prices can be reduced with increased returns for the fishermen.

The markets in Bombay can at present take only a limited quantity of fish. Even with the cold storage facilities available in the city, it is not practicable under present refrigeration conditions to move the fish inland by rail from Bombay if it has already been in transit by sea. In view of this, it is necessary to consider the export of fresh fish to the interior of the country by rail from landing places in Saurashtra itself. At present about 5% of the total catch is iced and exported by rail to Ahmedabad, Ajmer, Abu, Baroda, Surat, Billimora, Navsari and Bombay. It takes about 24 hours to reach Bombay but the condition of fish deteriorates due to rough handling and lack of insulated storage. The normal charges for transport of fish by rail from Veraval to Bombay is as follows:

VERAVAL TO BOMBAY	PER MAUND OF 40 LBS.
Rail charges	Rs.3-13-0
Handling charges	Rs.0-10-0
Ice	Rs.1-0-0
Total per md.	Rs.5- 7-0

Even though the space available for the transport of fish by rail has been increased from 100 to 200 cases in 1952, this quota was much below the requirements of about 250 cases during the season. The high cost of transportation naturally affects the price of fish received at the producing centres. However, transport by rail is a necessity and more fish should go to Ajmer, Abu, Bikaner, Jaipur, Delhi, Dehradun, Ahmedabad etc. This can only be successfully effected by providing facilities at landing centres for cold storage and cheap ice, reduction of freight charges, faster and larger carriages and refrigerated cars.

Road transport, which is by country carts, is resorted to in Saurashtra only for nearby towns, although iced fish is transported from Jamnagar by carts and lorries. The cured and dried fish is exported to Ahmedabad in North Halar State by country carts and camels.

The prices ruling in Bombay for prime fish, iced and chilled, are shown in Appendix II. As fish marketing in Saurashtra depends entirely upon export of fish and fish products, the following facilities are considered highly desirable. More fresh fish must be sent with ice instead of as cured or semi-dried fish, although Harpodon will still have to be sundried until canning is taken up. An iced "Ghol" weighing 20 lbs is valued in Sautrashtra @ Rs.4/- and at Bombay Rs.7/- to 7-8-0, while the same fish salted fetches only Rs.2-15-0 to 3/- due to loss in weight and palatability. Ice and salting charges, labour and transportation remaining the same, curing could be eliminated to a great extent if ice factories, cold storages, refrigerated wagons, cheap transport charges and carrier launches are available at prime fish-producing centres like Veraval, Mangrol, Porbandar and Jamnagar. In the case of dried, semi-dried or salted fishes the existing transport methods are adequate, if the charges are reduced.

3. PRESERVATION OF FISH

The methods of fish preservation in Saurashtra State depend mainly on the nature of the market and transport conditions and may be divided into five categories:

1. Drying
2. Salting and drying/Dry curing
3. Icing and chilling
4. Manure making
5. Processing fins, maws and oil

The quantities of fish utilised for the various methods of processing in Saurashtra in 1951-52 are presented in Appendix III.

a) SUNDRYING

The most important fishes which are sundried are Harpodon nehereus, Coilia dussumierii, and Penaeus and Metapenaeus spp.

Out of the total catches of 955,000 maunds 625,500 maunds, or 65% are sundried. Except for Coilia, shore perches and small Sciaena, sundrying of Harpodon (Bombla) or Perches (Jinga) has attained a satisfactory standard.

i. SUN DRYING OF "BOMBLA" (HARPODON NEHEREUS)

The Gujrat fishermen of Kolak, Umarsadi, Daman etc. come to Rajpara, Simar, Nawabunder and Jafrabad during the season (from November to the end of February) to fish in the inshore waters for Bombla which is then preserved. Special raised scaffoldings with wooden poles and thick coir ropes of 1 to 1½" diameter are constructed. The fish is washed well in sea water and split open into two except near the tail and is hung over the ropes without any application of salt. The fish is thus sundried within 72 hours, with a loss of about 70% in weight. This method of drying is quite hygienic. They are then packed neatly in bundles of 1,000 fish. The total quantity of Harpodon dried during 1951-52 was 575,460 mds.

ii. MURAENOSOX (WAMS) require more time for drying and the finished product is not as attractive as Harpodon. The processing of "Bombla" and "Wams" takes much time and the fishermen therefore employ special labour, each boat tindal engaging about 10 to 12 labourers who process about 50 to 70 maunds of fish per day and are paid in kind.

iii. SUNDRYING OF PRAWNS

The Gulf of Kutch coast produces about 140,000 maunds of prawns every year. The prawns are boiled in empty 4-gallon kerosene tins with about 1/8 part of salt and spread on the sand or on bamboo mats for drying. This process takes about 48 to 50 hours, when the prawns are placed in gunny bags and vigorously beaten. The shells of prawns, except the telson and part of the carapace, are completely removed by this process and the contents are then seived to obtain full brown prawns, 1½ to 2" in size which are then finally packed in gunny bags. Seven to 7½ mds. of fresh prawns yield about 1 maund of processed prawns and 2½ mds. of prawn shell manure. Owing to the abundance of prawns and as the season lasts from August to November, each boat has to process about 20 maunds of prawns per catching day; hence preboiling may not always be possible. Prawns which are dried on sand without boiling are whitish and brittle and are of second class quality. During 1951-52, the fisheries department demonstrated to the fishermen hygienic method of drying prawns. These prawns had a chocolate hue resembling the Karachi prawns and sold at Rs. 30 to 35 per maund, i.e. a 200% increase in price.

Semi-drying of prawns is done only by the Fisheries Department. The prawns are boiled for about 10 minutes, in a saturated solution of salt and immediately cooled for about an hour. They are then shelled, dried for 24 to 36 hours and packed. Only large prawns 6" to 7" long are suitable for this kind of processing. 6 lbs. of fresh prawns give about 1 lb. of semi-dried prawns, orange brown in colour and very attractive. During 1951-52, about 1,200 lbs. of semi-dried prawns were manufactured and sold at Rs. 2/- per lb.

b) SALT CURING

About 14% of the fish are cured by salting in this State. During 1951-52 133,760 maunds of fish were salted, out of which 78,220 mds. were Sciaena and Polynemus, and 64,204 mds. consisted of Hilsa, Perches, Mullets, Sharks, Rays, Pomfrets, Sea breams etc.

Wet curing is the most important method. The State has two good fish curing yards at Salaya and Nawabunder but the facilities offered, (which include a subsidy of 25% of the cost of salt), are not properly used and salt is usually taken on board the "Machwa" boats. The larger fish, such as the 3½ ft. Sciaena and Polynemus are split up the belly, gutted, washed in sea water and salted. The quantity of salt used for preservation is about 25 to 30% of the total weight of fish. The "Ghol", "Dara" and "Palla" fishermen fishing in Halar use about 23,000 maunds of salt from March to May. Sciaena and Polynemus lose about 50% of their weight when cured. They are not spread out and dried.

c) CHILLING AND ICING

Out of a total amount of fish exported, 12% or 114,600 maunds are sent, iced and chilled to Jamnagar, Jodiya, Salaya, Veraval, Porbandar and Mangrol. A great amount of fish, especially pomfrets is exported by sea from Veraval and Mangrol. Jamnagar exported during 1951-52 about 7,000 maunds of Sciaena and Polynemus chilled with crushed ice. The sea trade is by mechanized carrier launches or by country craft. This fish may be thus conserved for some 30 hours, as well-packed, finely-crushed ice is placed in large quantities between the layers. About 10 maunds of ice are used for 9 maunds of fish, and a profitable trade by sea is carried on between Saurashtra and Bombay city.

Iced fish is also exported by rail from Jamnagar, Salaya, Jodiya, Veraval and Porbandar, and through Bombay to Surat, Billimora, Ajmer, Ahmedabad, Abu and Rajkot. Each maund of fish is packed with an equal quantity of ice in deal wood cases. Jamnagar, Salaya, and Jodiya export about 50 to 60 cases (each containing 2 maunds) per day during the season and Veraval and Porbandar about 80 to 90 cases, which is the maximum quota allowed by railway. Only good table fishes like perches, pomfrets, sea breams, mullets, hilsa etc. are despatched to these places. These quantities might be increased with better storage and transport facilities as is indicated earlier.

During 1951-52 and until June, 1952, the Japanese trawler transported about 22,500 maunds of fish preserved in her 80-ton cold storage hold to Bombay.

d) MANURE

During 1951-52 the State produced about 23,850 maunds of fish manure. No special technical method is used for the disintegration of the fish and the fishermen dry the unsaleable, inedible or small fish into manure. The Jaffarabad and Nawabunder fishermen make manure out of Coilia dussumerii, young and spoilt Harpodon, Trichiurus, Stolephorus and rays. The manure is coarse and contains only about 4% of nitrogen by weight. It is packed in gunny sacks and sold at Rs. 2/2/- a maund. The fishermen of Malia and Mahuva make manure out of prawn shells: this manure is not properly sieved and graded and contains considerable quantities of sand. The prawn manure made by the Department of Fisheries was of a fine variety and contained about 5½% of nitrogen. The Department demonstrated to the fishermen of Veraval how to utilise guts and gills of fish and heads of sharks and rays as manure.

As far as possible salt curing will be discouraged, and chilling with ice and cold storage preservation promoted, as fresh fish fetch better prices.

e) PROCESSING OF FINS AND MAWS

The Department of Fisheries has had considerable success in introducing and improving the methods of processing shark fins and fish maws. The fins of all varieties of Rhynchobatus and Carcharius above 5 feet in length are now cut off at their joints, the flesh removed, washed, lime applied and dried for 48 hours. The State now produces 2,600 maunds of this valuable by-product which commands a good price. The dark fins fetch about Rs.1/4/- per lb. of all sizes and white fins of Pristis and Rhynchobatus fetch Rs. 2/- to Rs. 2/4/- a lb. The air bladders of Sciaena, Polynemus, Lates, Sciaenoides, Muraenesox and Arius are detached from the fishes, immediately split, blood spots and blood vessels removed, washed in sea and fresh water and dried for 48 hours. In the case of large bladders of Sciaena or Polynemus weights are placed over them to spread them evenly. The resulting fine isinglass has a yellowish white, semi-transparent hue and they are sold at about Rs.3/- per lb.

APPENDIX I

AVERAGE RATE FOR FISH (WHOLESALE) 1950-51 & 1951-52

(All zones in maunds of 40 lbs. approximately)

	1950-51	1951-52
1. Pomfrets (white & black)	15-0-0	16-8-0
2. Seer, Hilsa, Surmai	9-0-0	10-0-0
3. Perches	7-0-0	8-0-0
4. Ghol & Dara (Sciaena and Polynemus)	7-0-0	6-0-0
5. Mullets	6-0-0	7-0-0
6. Fresh prawns	5-0-0	7-0-0
7. Dried prawns	18-0-0	32-0-0
8. Cured fish A.	13-8-0	14-0-0
9. Cured fish B.	10-0-0	10-0-0
10. Bomla (Harpodon)	5-0-0	5-4-0
11. Mixed-Dhoma etc. (Muraenosox)	5-0-0	5-4-0
12. Sharks	4-0-0	5-0-0
13. Rays	2-8-0	3-0-0
14. Fins (black and white)	45-0-0	90-0-0
15. Maws (class I) air bladder	45-0-0	100-0-0
16. Manure	2-8-0	2-8-0

APPENDIX II

BOMBAY MARKET FOR SAURASHTRA FISHES IN 1951-52

		In season	Beginning, end and out of season
1.	(a) Pomfrets	28-0-0	35-0-0
	(b) Seer (Cybium)	21-0-0	23-0-0
	(c) Ghol, Dara	12-8-0	20-0-0
2.	(a) Prawns dried (i)	40-0-0	50-0-0
	(b) Fins	100-0-0	120-0-0
	(c) Maws	120-0-0	150-0-0
	(d) Manure	6-0-0	7-0-0
	(e) Cured Ghols etc.	20-0-0	30-0-0
3.	(a) Bomla dried	15-0-0	25-0-0
	(b) Mullets etc.	12-0-0	15-0-0
	(c) Miscellaneous	10-0-0	15-0-0

APPENDIX III

STATEMENT OF QUANTITY OF FISH UTILISED FOR VARIOUS METHODS OF PROCESSING IN SAURASHTRA in 1951-52

Sl. No.	Type of processing	Quantity of fish processed -mds.*	Types of fish treated Kind of fish	%	Remarks
1.	Sun-dried	625,500 mds.	Bombay duck	-59.8	
			Eel	- 3.25	
			Coilia	- 2.25	
2.	Salt cured	133,760 mds.	Sciaena, Polynemus	8.27	
			Hilsa, Perches, Mullets	5.73	
3.	Ice and Chilled fish and cold Storage.	114,600 mds.	Pomfret	5.76	
			Hilsa, Perches	3.84	
			Jap. landings	2.4	
4.	Fresh fish	52,520 mds.	All kinds	- 5.5	
5.	Manure-fish maws etc.	25,000		- 2.8	
6.	Boiled and Sundried	3,620	Penaeus Spp.	- 0.4	Most of the prawns processed are caught in the waters of Kutch.
	Total	955,000		100	

* md. = 40 lbs.